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Stock Assessments for British Columbia Herring in 1990 and Forecasts of the Potential Catch in 1991

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Nanaimo, British Columbia V9R 5K6

1991

**Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2119**



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Cat. No. Fs 97-4/12119E

ISSN 0706-6473

Correct citation for this publication:

Haist, V. and J. F. Schweigert. 1991. Stock assessments for British Columbia herring in 1990 and forecasts of the potential catch in 1991. Can. Manusc. Rep. Fish. Aquat. Sci. 2119: 60 p.

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ABSTRACT

Haist, V. and J. F. Schweigert. 1991. Stock assessments for British Columbia herring in 1990 and forecasts of the potential catch in 1991. Can. Manuscr. Rep. Fish. Aquat. Sci. 2119: 60 p.

Herring stock abundance in British Columbia waters was assessed for 1990 and forecasts were made for 1991 using two analytical methods: (1) escapement model; and (2) age-structured model. Diving survey data were utilized in the escapement model wherever available.

Forecasts of pre-fishery biomass are obtained by weighting the estimates from the two models. The forecasts are for 80,800 tonnes to the northern and 105,600 tonnes to the southern stock assessment regions. These estimates represent a decrease of 23% in the northern areas and a 5% increase in the southern areas relative to the 1990 forecasts.

The recommended 1991 catch (20% of the 1991 forecast herring run) for the entire B.C. coast is 37,280 tonnes. All areas should be available to the fishery in 1991.

Key words: *Clupea harengus pallasii*, Pacific herring, stock assessment, forecasts, age-structured analysis

RÉSUMÉ

Haist, V. and J. F. Schweigert. 1991. Stock assessments for British Columbia herring in 1990 and forecasts of the potential catch in 1991. Can. Manuscr. Rep. Fish. Aquat. Sci. 2119: 60 p.

L'abondance des stocks de hareng en Colombie-Britannique a été évaluée en 1990 et des prévisions ont été faites pour 1991 à l'aide de deux méthodes d'analyse: le modèle de l'échappée et le modèle en fonction de l'âge. Des données d'études en plongée ont été utilisées dans la mesure du possible dans le modèle de l'échappée.

Les prévisions concernant la biomasse avant la pêche ont été obtenues en pondérant les estimations effectuées à l'aide des deux modèles. Les prévisions donnent 80 800 tonnes pour les stocks de la région du nord et 105 600 tonnes pour les stocks de la région du sud. Ces estimations représentent une diminution de 23% dans les secteurs du nord et une augmentation de 5% dans les secteurs du sud par rapport aux prévisions de 1990.

La prise recommandée en 1991 (20% des prévisions de remonte de hareng pour 1991) pour toute la côte de Colombie-Britannique équivaut à 37 280 tonnes. Tous les secteurs devraient être ouverts à la pêche en 1991.

Mots-clés: *Clupea harengus pallasii*, hareng du pacifique, évaluation des stocks, prévisions, analyse en fonction de l'âge

1. INTRODUCTION

1.1 GENERAL

Herring are an important component of the British Columbia commercial fishery with catch records dating from 1877. In the early 1900's the fishery was primarily for a dry salted market and catches were relatively low. During the 1930's a fishery for reduction purposes developed and catches steadily increased. Very large catches (200,000 tonnes annually), in the early 1960's in conjunction with a series of poor recruitments led to the collapse of the reduction fishery and closure in 1968. Cessation of the intensive reduction fishery resulted in a gradual recovery of stocks.

In 1972 a herring fishery for a roe product developed. These fisheries occur just prior to spawning when the fish are tightly schooled and highly aggregated. Initially the roe-fisheries were managed in-season to fixed escapement targets (Hourston 1981). This management system was untenable because of problems in obtaining accurate in-season stock estimates, uncertainty about appropriate escapement targets, and difficulty in controlling fishing effort. Since 1983, herring fisheries have been managed with a fixed quota system. Under this system catch levels are determined prior to the season based on a fixed percentage (20%) of forecast stock abundance.

In this report we present stock assessments from two analytical models which have been developed explicitly for B.C. herring: (1) an escapement model (Schweigert and Stocker 1988); and (2) an age-structured model (Fournier and Archibald 1982). Both models reconstruct stock abundance for the period 1951-1990 and forecast pre-spawning abundance for the 1991 season. Forecasts of recruit spawners are presented as poor, average, and good based on means observed historically. This report does not discuss the development and evaluation of empirical models for forecasting recruitment, as results of these studies are presented elsewhere (eg. Schweigert and Noakes 1991, Stocker and Noakes 1988).

Results in this report were presented to the PSARC (Pacific Stock Assessment Review Committee) Herring Sub-Committee in September, 1990.

1.2 DATA BASE

The primary data sources for the stock assessments are spawn survey data, commercial catch landing data, and age composition data from biological samples of commercial fishery, pre-fishery charter, and research catches. These data are available on

computer files for the period 1951 to 1990. This time span includes the reduction fishery period to 1968 and the subsequent roe fishery period starting in the early 1970s.

Of the three data sets, the spawn data contain the largest measurement errors. We feel that the quality of spawn surveys has improved greatly over the 40 year span of these observations. This improvement is a result of increased numbers of people and vessels being involved in spawn surveys, increased attention to data measurements, increased coverage of subtidal spawnings, and increased research on estimating egg deposition from spawn observations. The consistent observations made during the 40 years of spawn surveys are the length, the width, and a measure of intensity of spawnings. The escapement model estimates absolute egg numbers from these observations and includes a width conversion to adjust for the inability to survey subtidal spawns adequately. Since 1987 an increasing number of spawn beds have been surveyed using SCUBA methods. We assume these surveys provide reasonably accurate estimates of spawn bed width and egg density and these data have been used in the escapement model where available. The age-structured model uses a spawn index which sums lengths multiplied by standardized widths and intensities.

Catch information was obtained from landing slip data. Both models use the landing slip data summed by season (seasons run from July 1 to June 30). The 1989/90 catch figures are based on hailed estimates because sales slip data were not available for timely analysis.

Age structure data are used in both models. The information from catch samples are used for years when there were commercial fisheries. Pre-fishery charter samples are used in addition to catch samples for areas with no fisheries or when catch samples do not appear to be representative. Additional data used in the age-structured model are annual average weight-at-age.

1.3 STOCK CONSIDERATIONS

The stock concept used for managing British Columbia herring is a compromise between biological and management considerations. Given poor or incomplete knowledge of stock structure it is prudent to manage fisheries at the level of the greatest potential stock diversity. Unfortunately, we do not feel that stock forecasts for smaller geographic regions than used in the current assessments would be accurate enough for fisheries management. Therefore, we recommend that fisheries should be spread throughout the assessment regions to prevent possible overexploitation of individual spawning groups.

Two stock groupings used for this year's assessment are modified. At the 1989 PSARC herring meeting it was decided to adopt revised boundaries for the Queen Charlotte Islands and northern west coast of Vancouver Island stock assessment regions. The current herring stock assessment regions are shown in Figures 1.1 and 1.2.

The Queen Charlotte Islands stock assessment region has been extended to include Cumshewa Inlet in the north and Louscoone Inlet in the south. The stock concept for the Prince Rupert District remains unchanged encompassing Statistical Areas 3 to 5. The central coast stock concept separates the major migratory stocks from the minor spawning populations in the mainland inlets. The areas included in the central coast assessment region are Statistical Area 7 plus Kitasu Bay in Area 6 and Kwakshua Channel in Area 8. The Strait of Georgia is separated into two stock groupings. The northern area includes all of Statistical Areas 14 to 16, 17N, and Deepwater Bay and Okisollo Channel in Area 13. The southern stock comprises Areas 17S, 18 and 19. The two stock groupings used for the west coast of Vancouver Island are southern (Areas 23 and 24) and northern (Area 25). The northern area previously included Areas 25 through 27.

Biomass estimates from the escapement model are also presented for areas outside the major assessment regions. The level of geographic aggregation used for these estimates is the section (Haist and Rosenfeld 1988).

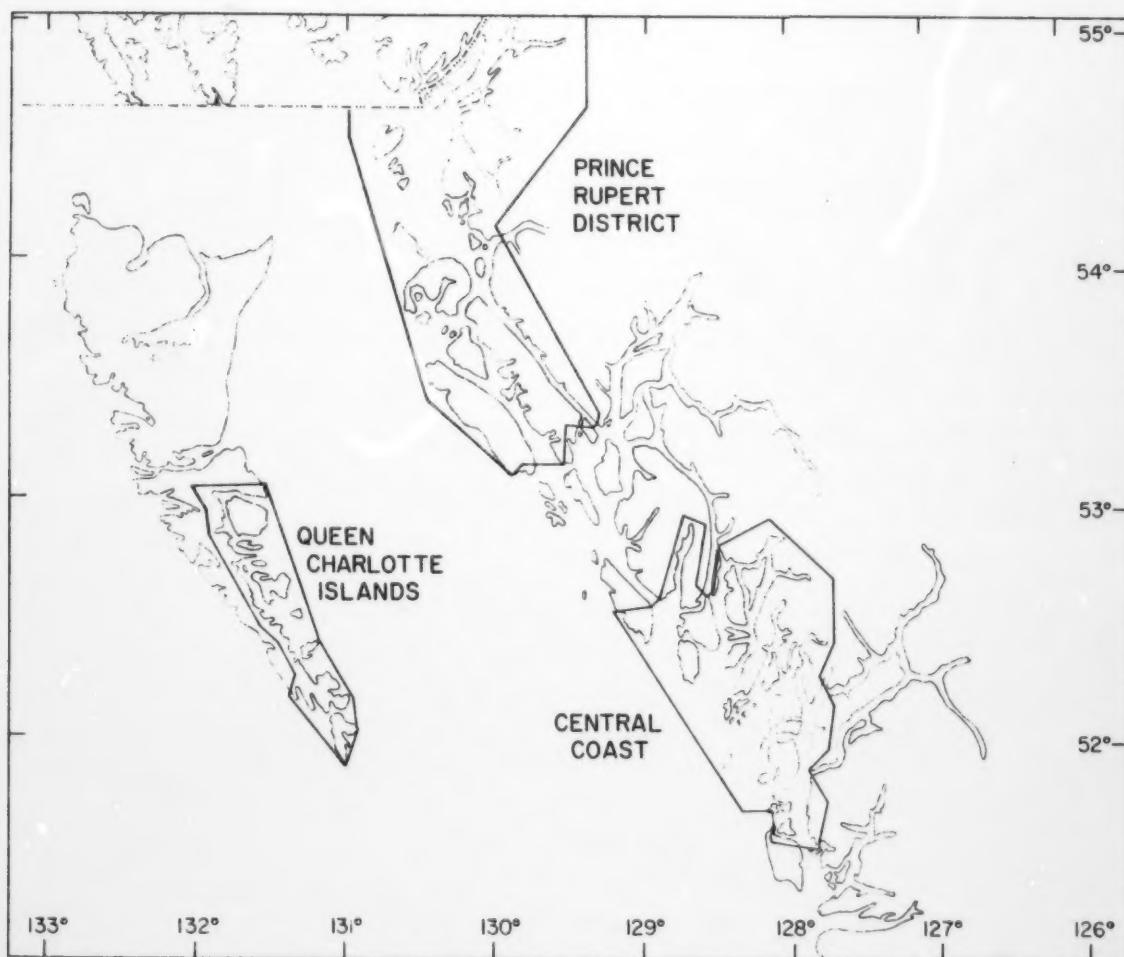


Fig. 1.1. Herring stock assessment regions in northern British Columbia.

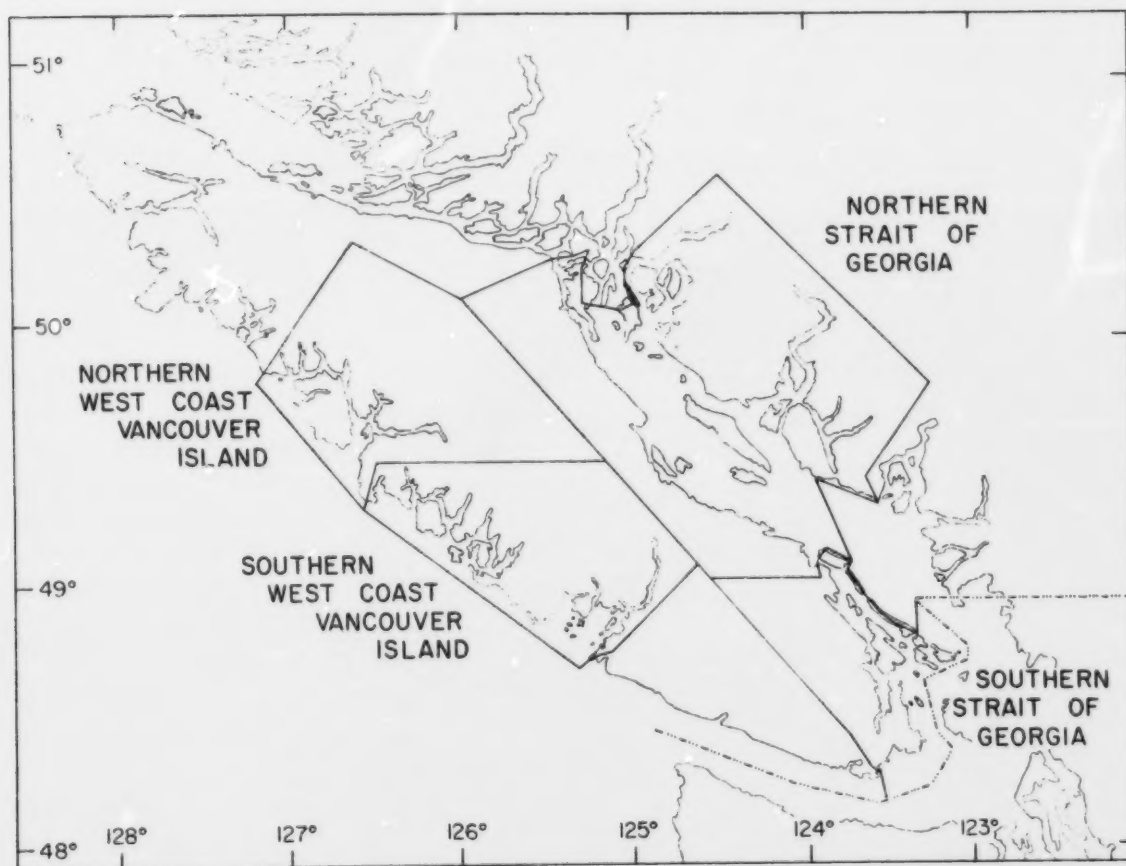


Fig. 1.2. Herring stock assessment regions in southern British Columbia.

2. ESCAPEMENT MODEL

2.1 INTRODUCTION

The escapement model, developed for the 1984 assessments (Haist et al. 1985; Schweigert and Stocker 1988), is based on information on spawn deposition and provides an empirical estimate of escapement from the fishery. For most stock assessment regions recent estimates of escapement are based on a combination of surface and SCUBA survey data. Beginning in 1987, an increasing portion of the herring spawns have been surveyed by SCUBA methods (Table 2.1).

In this year's assessment, estimates are presented for the major migratory stocks in the 7 assessment regions (Tables 2.2 and 2.3) and for the minor stocks not included in these regions (Tables 2.4 - 2.7).

2.2 METHODS

In the escapement model, the forecast run size is based on the estimated escapement in the previous season, growth of the fish during the current season, an average annual survival rate (0.64), and an estimate of recruitment to each stock. Recruitment is estimated for poor, average, and good levels by calculating the means of the third poorest, the middle third, and the third best recruitments observed during the historical time series from 1951-1990. Estimates of total catch (tonnes) and spawn abundance (billions of eggs) are converted to fish-at-age based on the sampling data for each area. For each area the age structure and average weight-at-age are calculated from samples available for that region. For some years no data are available for a region and information from an adjacent area is utilized in the analysis. Forecasts of repeat spawners and recruit fish are converted to forecast tonnages using average weights-at-age as outlined in Haist and Schweigert (1990). The method for estimating escapement from surface and dive survey data is described below.

Biomass estimates

Escapement from the fishery plus total catch provides an estimate of the pre-fishery stock biomass for each assessment region. The estimated escapement for each region is derived from information on spawn deposition. Dive survey observations are used directly while surface survey observations are adjusted based on calibration equations derived from replicate surveys (Schweigert and Stocker 1988). Total egg deposition is calculated as the product of: total spawn length; observed or adjusted spawn width; and egg density as

estimated from the average surface layer estimate, or average predicted egg density from quadrat observations, or average egg layer and plant densities in *Macrocystis* sp. beds. Egg deposition estimates for all spawn beds are summed within each assessment region and the total egg deposition is converted to tonnes of spawning fish based on the average estimate of 100 eggs per gram of fish.

Surface Surveys

Estimates of spawn width and average egg layers from surface surveys are adjusted to comparable dive survey estimates. The calibration equations used for the 1990 assessment are the same as those used in last year's assessment.

The calibration equation, with parameter estimates, used to adjust surface survey spawn width estimates to comparable diver width estimates is:

$$\text{ADJUSTED WIDTH} = 75.275 + 0.816 \text{ SURFACE SURVEY WIDTH.}$$

The equation used to estimate the average density of eggs (thousands per m²) for each spawn from the estimate of average egg layers is:

$$\text{EGGS} = 202.093 + 67.345 \text{ AVERAGE SURFACE LAYERS.}$$

Surface survey data are adjusted using the foregoing equations in all areas except for Johnstone Strait (Statistical Areas 9-13). In this area no adjustment is applied to the spawn widths as previous dive surveys in the area (Schweigert and Haegele 1988a, b) indicated that widths were accurately assessed from the surface.

SCUBA Surveys

For SCUBA surveys spawn bed lengths are determined by exploratory raking or snorkelling and spawn bed widths estimated as the mean of all transect lengths within the spawn bed. Estimates of mean egg density are based on a two-stage sampling design (Schweigert et al. 1985, 1990). Average egg density for each spawning area is estimated as the weighted mean of the means of a series of quadrats located along each transect. For each quadrat observations are made on several variables: type of algal substrate; proportion of the quadrat covered by each algal type; number of layers of eggs on each algal type; proportion of the bottom substrate covered by eggs; and an estimate of the number of egg layers on bottom substrate. In some areas assessments are also made of the egg deposition on the giant kelp as described below.

Egg deposition for each sampling quadrat is estimated from the prediction equation described in the 1989 assessment (Haist and Schweigert 1990). Egg density for each vegetation subfraction is estimated as follows:

$$\text{EGGS}_i = 1038.5617 L^{0.6856} P^{1.4189} V_i Q_j$$

where EGGS_i = estimated number of eggs in thousands per m^2 on vegetation type i ,

L = number of layers of eggs on algal substrate i ,

P = proportion of quadrat covered by algal substrate i ,

V_1 = 1.0224 parameter for sea grasses,

V_2 = 1.2247 parameter for rockweed,

V_3 = 0.8730 parameter for flat kelp,

V_4 = 1.2254 parameter for other brown algae,

V_5 = 0.9482 parameter for leafy red and green algae,

V_6 = 1.0000 parameter for stringy red algae,

Q_1 = 0.5387 parameter for 1.00 m^2 quadrats,

Q_2 = 0.5664 parameter for 0.50 m^2 quadrats,

Q_3 = 1.0000 parameter for 0.25 m^2 quadrats.

Total egg density (thousands of eggs per m^2) for each quadrat is then estimated by summing the egg density estimates over the vegetation types,

$$\text{EGGS} = \sum_i \text{Eggs}_i$$

Eggs on Bottom and *Macrocystis*

Eggs on rock are estimated from the product of the proportion of the quadrat covered by eggs, number of egg layers, and 340,000 eggs/ m^2 (Haegele *et al.* 1979). Eggs on rock also includes eggs on other inorganic substrates as well as egg deposition on very short (1-2 cm) red algae, calcareous encrusting algae, worm tubes, logs, etc. Total egg density for each quadrat is the sum of eggs on vegetation plus eggs on rock.

In some northerly areas such as the Queen Charlotte Islands and the Prince Rupert District a significant proportion of the total egg deposition occurs on the giant kelp, *Macrocystis* sp., with smaller amounts in some localities on the central coast and west coast of Vancouver Island. The approach we have adopted for routine SCUBA surveys follows that outlined by Haegele and Schweigert (1985). The transects used to assess egg density on understory vegetation are enumerated for *Macrocystis* plants and fronds within 1 m on either side of the transect line. An egg prediction equation has been developed (Haegele and Schweigert 1990):

$$\text{EGGS/PLANT} = 0.073 \text{ LAYERS}^{0.673} \text{ HEIGHT}^{0.932} \text{ FRONDS}^{0.703}$$

where EGGS/PLANT = total number of eggs on the *Macrocystis* plant in millions,
 LAYERS = average number of egg layers on each *Macrocystis* plant,
 HEIGHT = total height of the *Macrocystis* plant in metres,
 FRONDS = total number of fronds per *Macrocystis* plant.

This equation estimates the number of eggs occurring on a plant of a specific height with a certain number of fronds and egg layers. In practice, the synoptic SCUBA survey estimates only the average number of egg layers per plant, the average plant height, and the average number of fronds per plant along each transect. These quantities are used in the above equation to estimate the total egg numbers per plant for each transect. These estimates are averaged across transects to obtain an average number of eggs per plant for the entire *Macrocystis* bed.

This information may then be combined with the estimate of the density of plants and the estimated area of the *Macrocystis* bed to obtain an estimate of the total number of eggs deposited on the kelp. This egg deposition is then added to the deposition on the understory vegetation for the area.

Enumerated Egg Samples

Samples of the algae and attached eggs from entire quadrats were collected in 1990 from the Prince Rupert District as a check on the accuracy of the egg density prediction model. This area was chosen because of concern about an apparent stock decline. A total of 54 samples were obtained. The average egg counts for the preserved samples was 298,922 eggs/m² while the average of the predictions from the statistical model is 670,704 eggs/m². The reason for this discrepancy is not clear but many of the egg samples obtained were near to hatching. We have found that this can result in underestimates of egg numbers because the egg cases begin to rupture during processing releasing the larvae. Although larvae are counted and added to the remaining eggs some larvae are lost in the sample processing.

In addition, samples were preserved for the first time in a modified form of Gilson's fluid which doesn't contain mercury. It appears that the absence of mercury in the Gilson's fluid makes the eggs more fragile resulting in increased egg rupturing even in samples which are collected earlier in the incubation period.

A comparison of egg counts from duplicate samples taken in Lambert Channel and preserved in both Gilson's fluid containing mercury and the modified non-mercuric Gilson's solution is shown in Table 2.8. A paired t-test analysis found no significant difference between egg counts from the mercuric and non-mercuric Gilson's fluid ($p > 0.50$). Therefore, it appears that most of the discrepancy between model predictions and egg counts is due simply to the collection of samples which were too near to hatching and normal sampling variation.

2.3 RESULTS

A summary of the spawn survey coverage for the British Columbia coast from 1987 to present is presented in Table 2.1. It is evident that the majority of the spawn deposition is now being surveyed by SCUBA methods. No surface surveys were conducted in the Prince Rupert District and were conducted in only a few locations in the Queen Charlotte Islands. Due to the large number of spawn locations in the central coast about half of the spawn was surveyed by surface methods in 1990. In the Strait of Georgia and the west coast of Vancouver Island the majority of spawns were surveyed with SCUBA. Unfortunately, significant spawns in Hesquiat Harbour were not surveyed at all.

Estimates of stock abundance for the seven stock assessment regions are presented in Tables 2.2 and 2.3 and discussed in Section 4. Estimates of abundance for the minor stocks are presented in Tables 2.4 to 2.7. There are always problems in assessing stocks in more remote locations due to inadequate spawn survey coverage and a general absence of age-structure data, so absolute estimates of abundance are probably not very accurate. From the available data abundance trends for the minor stocks generally follow those of the nearby stock assessment region. The stocks in Area 2W appear healthy in relation to historical levels and could again be considered as a potential area for a roe fishery. The minor stocks in the central coast are also not surveyed with sufficient regularity to discern possible trends, but no major fishable biomasses are apparent. The Johnstone Strait stocks appear to be below the long term average based on recent surveys, but coverage may be incomplete. The stocks on the northern west coast of Vancouver Island receive intermittent survey coverage and show no clear trends. There is no large fishable biomass in this area.

Table 2.1. Kilometers of spawn surveyed by dive and surface methods for major and minor stocks on the British Columbia coast, 1987-1990.

Assessment Region	1987			1988			1989			1990		
	Dive	Surface	Total	Dive	Surface	Total	Dive	Surface	Total	Dive	Surface	Total
Queen Charlotte Islands	0.0	35.7	35.7	28.2	7.9	36.1	48.8	18.4	67.2	63.0	3.0	66.0
Prince Rupert District	0.0	83.6	83.6	55.0	5.7	60.7	40.1	0.9	41.0	47.4	0.0	47.4
Central Coast	0.0	86.5	86.5	32.6	112.7	145.3	25.1	105.1	130.2	73.6	73.9	147.5
N. Strait of Georgia	49.4	13.9	63.3	39.7	8.6	48.3	66.1	16.6	82.7	77.0	1.1	78.1
S. Strait of Georgia	25.2	2.2	27.4	12.6	5.6	18.2	24.8	2.3	27.1	40.5	0.0	40.5
S.W.C. Vancouver Is.	31.1	10.4	41.5	35.1	23.9	59.0	47.3	6.6	53.9	26.5	10.7	37.2
N.W.C. Vancouver Is.	10.7	19.0	29.7	0.0	22.6	22.6	11.6	11.0	22.6	4.7	11.2	15.9
Other Areas	0.0	173.6	173.6	0.0	228.5	228.5	16.1	153.4	169.5	32.4	148.1	180.5
Coastwide Total	116.5	424.8	541.3	203.4	415.6	619.0	279.9	314.4	594.3	365.1	248.0	613.1

Table 2.2. Estimates of spawner biomass, catch, and total stock abundance (tonnes) for the northern stock assessment regions for 1951-1990.

Season	Queen Charlotte Islands			Prince Rupert District			Central Coast		
	Spawners	Catch	Stock	Spawners	Catch	Stock	Spawners	Catch	Stock
1950/51	4191	2847	7038	27967	45865	73832	20886	42458	63345
1951/52	3051	10147	13198	9957	52379	62336	10351	33195	43546
1952/53	5702	0	5702	14016	1865	15881	20187	768	20955
1953/54	11514	1786	13301	9951	27277	37228	16308	24616	40925
1954/55	5840	498	6338	12738	17806	30544	16061	11594	27655
1955/56	5592	77461	83053	12506	10182	22688	11557	43627	55185
1956/57	1495	21803	23298	19301	28035	47336	5960	23261	29221
1957/58	783	11147	11930	8514	4523	13037	8276	9849	18125
1958/59	8085	6828	14913	16197	10224	26421	7409	27870	35279
1959/60	7017	0	7017	13146	18476	31621	20331	4037	24368
1960/61	8612	576	9188	14482	42746	57228	8393	31704	40097
1961/62	5338	7632	12970	20094	27660	47754	22499	15709	38208
1962/63	4465	14705	19170	15151	40228	55379	10918	44054	54972
1963/64	4830	28882	33712	16316	30340	46655	11690	32064	43754
1964/65	1889	35448	37337	6278	44211	50488	4486	15670	20156
1965/66	3525	2746	6271	5769	17295	23065	4990	37482	42472
1966/67	942	213	1155	3057	7998	11055	8219	21890	30109
1967/68	817	80	897	6508	2144	8652	8973	1529	10502
1968/69	1799	0	1799	900	547	1447	3959	100	4058
1969/70	8211	0	8211	11904	1498	13403	19352	209	19561
1970/71	12599	102	12701	9685	3500	13185	8029	3614	11642
1971/72	10845	3972	14817	10896	4494	15390	8583	9279	17863
1972/73	11772	7520	19292	11112	1607	12719	23747	7799	31546
1973/74	13139	6318	19457	8843	3819	12663	19662	8887	28550
1974/75	11525	7724	19249	10572	1702	12273	18952	8739	27690
1975/76	18615	14116	32731	15834	4307	20141	30004	12199	42203
1976/77	18206	12635	30841	15617	8142	23758	27962	11106	39067
1977/78	14994	11726	26720	7577	8588	16165	16712	14046	30758
1978/79	12150	7953	20103	13730	4317	18047	14408	5	14413
1979/80	25853	3316	29169	17155	3425	20580	30389	538	30927
1980/81	26983	5631	32613	17131	3090	20221	32771	2573	35344
1981/82	22013	3778	25792	14917	1984	16901	33660	6370	40030
1982/83	19944	5597	25540	26310	0	26310	41185	5640	46825
1983/84	22150	4719	26869	28013	3761	31774	27875	7193	35068
1984/85	17721	6109	23830	31994	6747	38740	24676	5209	29885
1985/86	6719	3503	10222	30186	8679	38865	21633	3386	25019
1986/87	15277	2061	17338	38140	6271	44411	28714	3615	32330
1987/88	16771	32	16802	32092	7968	40060	48385	4527	52912
1988/89	25821	1461	27283	12931	8474	21405	42133	9442	51574
1989/90	24164	6678	30842	19398	4068	23466	42333	7977	50311

Table 2.3. Estimates of spawner biomass, catch, and total stock abundance (tonnes) for the southern stock assessment regions for 1951-1990.

Season	Georgia Strait - North			Georgia Strait - South			WCVI - South			WCVI - North		
	Spawners	Catch	Stock	Spawners	Catch	Stock	Spawners	Catch	Stock	Spawners	Catch	Stock
1950/51	30795	17787	48582	3623	25824	29447	6510	15914	22423	9345	5908	15252
1951/52	27928	17635	45563	12440	28084	40524	6400	10630	17030	1851	16378	18229
1952/53	33442	4376	37817	33092	3966	37058	8918	20	8938	13198	0	13198
1953/54	23291	20560	43851	35352	44284	79635	5292	28699	33991	4522	4510	9032
1954/55	30962	26818	57780	30895	41619	72514	6439	6041	12479	3831	83	3913
1955/56	13908	27273	41181	14745	44572	59318	8769	17098	25867	12302	0	12302
1956/57	12652	21374	34025	6817	38202	45019	6246	2600	8846	16412	13	16424
1957/58	8288	9012	17299	17174	11616	28790	11648	513	12161	5715	43	5758
1958/59	16095	34189	50284	16121	15765	31886	6037	37385	43422	4793	31838	36631
1959/60	20903	22540	43443	9267	43107	52375	5612	17652	23264	948	36259	37207
1960/61	17094	15784	32878	9186	30410	39596	7804	13489	21293	3430	12946	16376
1961/62	16176	30358	46534	5448	34945	40393	9024	15597	24622	12802	8087	20889
1962/63	16106	33746	49852	8572	35101	43673	8544	4019	12563	1537	14187	15724
1963/64	15319	36808	52127	6760	40179	46939	17239	20230	37469	7302	1036	8337
1964/65	13512	27931	41443	2567	19888	22455	7069	14063	21132	5835	1983	7818
1965/66	4824	20996	25821	2805	12337	15142	3377	8169	11546	1935	2673	4608
1966/67	6781	11157	17938	2558	19885	22444	2163	9171	11333	3568	5974	9542
1967/68	6969	966	7935	5247	981	6228	4105	0	4105	3028	0	3028
1968/69	9063	325	9388	7494	420	7914	5539	0	5539	5555	0	5555
1969/70	22274	519	22793	12870	365	13235	16899	0	16899	4813	0	4813
1970/71	27393	948	28341	10879	745	11624	17904	0	17904	6329	0	6329
1971/72	14022	6443	20465	9153	2368	11521	17370	4285	21655	9929	2609	12538

Table 2.3. (Cont'd.).

Season	Georgia Strait - North				Georgia Strait - South				WCVI - South				WCVI - North			
	Spawners	Catch	Stock	Spawners	Catch	Stock	Spawners	Catch	Stock	Spawners	Catch	Stock	Spawners	Catch	Stock	Spawners
1972/73	15205	6679	21884	9812	970	10781	6120	10409	16529	6053	7894	13946	6053	7894	13946	6053
1975/76	38858	8163	47020	9295	4075	13370	27971	33441	61412	4216	5384	9601	4216	5384	9601	4216
1976/77	47284	11304	58587	6001	6205	12206	28556	26453	55009	5725	3590	9315	5725	3590	9315	5725
1977/78	52530	13874	66404	13633	10129	23761	18760	18050	36810	5233	4695	9928	5233	4695	9928	5233
1978/79	73180	8638	81819	19573	11699	31273	27937	9876	37813	22912	8817	31729	22912	8817	31729	22912
1979/80	53805	4525	58329	11808	1294	13102	26534	2276	28810	8369	1706	10075	8369	1706	10075	8369
1980/81	32192	7407	39598	12152	4645	16798	24090	4928	29017	7056	3162	10218	7056	3162	10218	7056
1981/82	64906	5746	70652	7852	7086	14939	10921	3110	14031	6466	2377	8843	6466	2377	8843	6466
1982/83	34396	16220	50616	11277	949	12225	10921	6141	17062	4667	2434	7102	4667	2434	7102	4667
1983/84	15927	9869	25797	11413	1175	12588	16033	5718	21751	2668	858	3526	2668	858	3526	2668
1984/85	20490	6239	26729	7630	791	8421	25889	178	26067	1376	0	1376	1376	0	1376	1376
1985/86	55423	287	55710	7824	307	8131	28490	204	28694	8893	0	8893	8893	0	8893	8893
1986/87	29568	5294	34861	9144	4059	13203	24254	13463	37717	6894	2471	9365	6894	2471	9365	6894
1987/88	22913	7500	30413	5206	715	5922	30036	9724	39760	6947	0	6947	6947	0	6947	6947
1988/89	52364	7077	59441	4481	1292	5773	34002	13289	47291	4258	0	4258	4258	0	4258	4258
1989/90	45737	4223	49960	13225	3266	16491	29620	9421	39041	8274	0	8274	8274	0	8274	8274

Table 2.4. Estimates of the total biomass and average reduction and roe catches (tonnes) for minor stocks in the Queen Charlotte Islands for 1951-1990.

Season	Section					Total	Section	
	001	002	003	004	005	Area 2W	022	023
1950/51	0	0	0	0	0	0	812	0
1951/52	0	0	0	0	0	0	638	0
1952/53	0	0	776	160	0	936	1723	0
1953/54	0	0	0	0	0	0	25304	0
1954/55	0	0	0	0	0	0	19017	0
1955/56	0	0	0	0	0	0	5896	93
1956/57	0	0	148	0	0	148	1193	0
1957/58	0	0	221	0	43	264	83	0
1958/59	1675	1144	1587	0	1026	5432	11177	0
1959/60	91	656	1376	0	111	2234	3623	0
1960/61	1158	422	531	0	389	2500	4279	0
1961/62	396	1925	1665	0	311	4297	8033	0
1962/63	0	2411	0	0	0	2411	3027	0
1963/64	433	1403	760	192	168	2956	4004	0
1964/65	285	0	303	106	1481	2175	5671	0
1965/66	0	66	26	0	18	110	3792	0
1966/67	81	1271	0	0	154	1506	637	178
1967/68	0	6	110	0	77	193	273	0
1968/69	26	297	321	0	935	1579	1174	0
1969/70	0	423	373	0	805	1601	1054	4979
1970/71	0	170	825	0	589	1584	2064	6495
1971/72	0	467	489	0	1995	2951	3550	7400
1972/73	0	139	1480	0	2347	3966	1136	9338
1973/74	0	0	1364	0	3001	4365	1625	6270
1974/75	0	314	1400	254	1570	3538	2211	5265
1975/76	0	417	489	0	1857	2763	2986	5070
1976/77	0	302	669	221	2442	3634	3081	4184
1977/78	640	0	2104	0	2240	4984	4035	3624
1978/79	1292	53	692	110	875	3022	1635	3541
1979/80	1157	1397	1907	0	2310	6771	31	0
1980/81	1289	4097	2188	435	1235	9244	711	2077
1981/82	0	6143	3544	439	4101	14227	876	563
1982/83	261	3560	4165	550	5149	13685	577	1816
1983/84	580	2654	1148	0	2095	6477	2318	1755
1984/85	0	2242	909	38	1993	5182	411	1247
1985/86	0	1168	314	0	1442	2924	2816	974
1986/87	0	2091	0	0	765	2856	903	968
1987/88	721	4307	1413	358	2334	9133	425	0
1988/89	0	2549	2948	0	3773	9270	0	677
1989/90	0	10232	2117	0	2648	14997	0	1200
Avg Biomass	252	1308	959	72	1257	3848	3320	1693
Avg Catch (1951-1967)	35	0	6	0	57	98	5197	5
Avg Catch (1972-1990)	0	110	120	0	266	496	169	805

Table 2.5. Estimates of the total biomass and average reduction and roe catches (tonnes) for minor stocks in the Central coast for 1951-1990.

Season	Section									Area 9	Area 10	Total
	061	062	063	064	065	066	082	083	084			
1950/51	0	0	12	115	0	3110	0	10	0	763	185	4195
1951/52	0	0	0	101	211	0	2374	10	0	554	69	3319
1952/53	0	0	0	0	0	0	0	0	0	196	650	846
1953/54	0	181	0	808	223	58	309	994	0	2170	481	5224
1954/55	0	367	95	2925	2118	113	710	274	270	5332	1400	13604
1955/56	0	271	48	16	280	9	0	307	18	163	148	1260
1956/57	6610	149	22	53	1805	0	1505	767	0	3077	2170	16158
1957/58	186	295	18	1	284	0	0	1754	0	634	440	3612
1958/59	1748	233	693	57	67	366	75	1134	0	2870	1234	8477
1959/60	19	615	2521	249	1644	0	0	330	26	405	586	6395
1960/61	82	673	678	12	3666	0	289	457	0	1041	924	7822
1961/62	70	2298	90	0	5056	138	6478	24	0	5826	1556	21536
1962/63	991	2506	1282	180	65	0	2345	1169	0	4106	497	13141
1963/64	1112	1578	2117	0	934	31	1509	953	529	8392	1203	18358
1964/65	3977	1237	137	0	656	40	353	673	634	1486	315	9508
1965/66	2827	1966	597	277	37	147	3251	822	978	5661	1354	17917
1966/67	2184	1761	131	117	191	0	270	270	530	3184	3507	12145
1967/68	498	59	53	1	0	0	0	913	48	376	442	2390
1968/69	0	0	6	35	0	0	299	16	0	115	46	517
1969/70	0	0	72	62	14	27	670	271	9	1573	339	3037
1970/71	0	0	44	15	28	0	258	484	201	627	809	2466
1971/72	0	0	15	0	0	436	165	420	248	1037	1167	3488
1972/73	0	77	45	0	0	0	147	138	1190	3846	136	5579
1973/74	0	39	37	0	0	0	66	134	625	1045	302	2248
1974/75	0	0	40	0	5	0	378	133	1148	867	299	2870
1975/76	0	193	0	0	30	0	119	146	905	739	179	2311
1976/77	0	0	32	0	2	0	0	140	490	670	60	1394
1977/78	57	0	4	0	0	0	39	67	244	429	214	1054
1978/79	0	211	0	0	0	163	0	43	221	120	81	839
1979/80	0	0	0	0	0	581	0	150	0	320	246	1297
1980/81	426	27	0	0	0	0	0	78	107	75	201	677
1981/82	664	0	0	0	0	0	0	40	0	1017	741	2287
1982/83	0	120	0	0	0	0	0	15	132	243	609	1119
1983/84	0	0	0	0	0	0	0	37	273	58	700	1068
1984/85	11	264	0	0	0	0	0	0	91	152	224	742
1985/86	0	796	0	0	0	0	0	109	49	1702	584	3240
1986/87	385	196	0	0	0	618	0	222	179	1540	78	3218
1987/88	0	0	0	0	0	0	68	256	9	1088	165	1586
1988/89	0	0	0	0	0	0	0	119	50	374	340	883
1989/90	0	49	502	0	0	0	0	17	105	942	71	1686
Avg Biomass	546	404	252	126	433	146	542	347	233	1620	619	5248
Avg catch (1951-1967)	1165	829	471	264	1013	144	1144	576	130	2477	811	9024
Avg catch (1972-1990)	35	0	0	0	0	0	0	0	111	188	81	394

Table 2.6. Estimates of total biomass and average reduction and roe catches (tonnes) for minor stocks in Johnstone Strait for 1951-1990.

Season	Section		Section	Other		Total
	Area 11	126	127	Area 12	Area 13	
1950/51	1	989	335	3251	116	4692
1951/52	4	2290	344	5717	90	8445
1952/53	0	202	258	1236	173	1869
1953/54	2	869	408	5102	80	6461
1954/55	6515	323	1073	1124	222	9257
1955/56	257	563	194	1089	518	262
1956/57	13	636	126	12191	81	13047
1957/58	15	30	180	4023	0	4248
1958/59	144	3431	1091	1625	298	6589
1959/60	668	976	2518	5553	480	10195
1960/61	266	819	282	4693	293	6353
1961/62	781	112	749	9323	404	11369
1962/63	2187	591	1039	8801	769	13387
1963/64	129	446	5753	5858	1618	13804
1964/65	1226	996	2894	11028	3147	19291
1965/66	1171	292	2109	18129	682	22383
1966/67	252	140	998	10660	3299	15349
1967/68	7	50	152	2727	3	2939
1968/69	21	194	189	1509	168	2081
1969/70	48	298	235	2674	176	3431
1970/71	69	153	97	1875	417	2611
1971/72	31	1504	1188	4163	745	7631
1972/73	12	1145	3568	8850	276	13851
1973/74	7	565	3580	1742	290	6184
1974/75	28	1158	3285	1810	619	6900
1975/76	33	1207	2018	805	119	4182
1976/77	15	406	1721	1145	108	3395
1977/78	16	565	576	248	61	1466
1978/79	60	64	71	175	178	548
1979/80	14	245	417	822	264	1762
1980/81	9	192	287	460	1351	2299
1981/82	0	141	550	67	252	1010
1982/83	17	95	243	101	135	591
1983/84	10	165	482	650	2	1309
1984/85	0	415	940	129	228	1712
1985/86	39	166	197	505	42	949
1986/87	13	148	171	488	96	916
1987/88	7	257	396	900	1	1561
1988/89	19	494	162	615	91	1381
1989/90	0	385	563	61	150	1159
Avg Biomass	353	593	1036	3548	450	5979
Avg Catch (1951-1967)	756	714	1083	5966	530	9050
Avg Catch (1972-1989)	1	231	88	771	41	1131

Table 2.7. Estimates of total biomass and average reduction and roe catches (tonnes) for minor stocks for the northern west coast of Vancouver Island 1951-1990.

Season	Section		Other	Total	Section			Other	Total
	262	263	Area 26	Area 26	272	273	274	Area 27	Area 27
1950/51	864	269	9	1142	622	1778	0	0	2400
1951/52	364	37	383	784	0	662	0	0	662
1952/53	2335	640	633	3608	273	6882	700	0	7855
1953/54	588	2408	691	3687	951	3156	342	1266	5715
1954/55	4203	889	180	5272	106	1385	0	5947	7438
1955/56	352	524	142	1018	0	6	0	0	6
1956/57	772	762	42	1576	0	772	0	0	772
1957/58	711	241	157	1109	0	327	0	0	327
1958/59	281	240	85	606	0	180	0	407	587
1959/60	2655	673	509	3837	168	185	0	0	353
1960/61	2710	1594	511	4815	305	670	43	456	1474
1961/62	1047	3866	422	5335	0	207	137	173	517
1962/63	3496	428	85	4009	0	1734	122	31	1887
1963/64	1196	456	0	1652	0	90	0	233	323
1964/65	724	1317	0	2041	1888	1801	50	11	3750
1965/66	1316	18	0	1334	213	56	0	862	1131
1966/67	463	659	0	1122	139	69	0	0	208
1967/68	61	0	0	61	0	208	0	240	448
1968/69	283	824	0	1107	1514	895	0	0	2409
1969/70	774	135	0	909	2011	206	249	0	2466
1970/71	741	646	0	1387	0	145	370	0	515
1971/72	2209	132	0	2341	0	69	424	0	493
1972/73	1732	0	0	1732	1799	788	349	0	2936
1973/74	1068	0	0	1068	0	526	0	0	526
1974/75	728	180	0	908	0	2809	0	0	2809
1975/76	575	0	0	575	12	402	221	0	635
1976/77	509	11	0	520	0	1117	155	48	1320
1977/78	0	0	0	0	3146	8234	125	0	11505
1978/79	0	0	0	0	3894	10141	0	0	14035
1979/80	0	0	0	0	8914	14428	0	0	23342
1980/81	0	0	0	0	0	6441	0	0	6441
1981/82	0	0	0	0	3576	4640	11	0	8227
1982/83	0	0	0	0	0	7642	0	0	7642
1983/84	0	0	0	0	0	3824	0	0	3824
1984/85	0	0	0	0	2151	289	0	0	2440
1985/86	0	0	0	0	0	3807	0	0	3807
1986/87	0	0	0	0	1967	2424	0	0	4391
1987/88	0	0	0	0	0	4868	0	0	4868
1988/89	0	0	0	0	2526	3122	0	0	5648
1989/90	0	0	0	0	1430	6335	0	0	7765
Avg Biomass	819	424	96	1339	940	2583	82	242	3847
Avg catch (1951-1967)	434	620	40	1094	100	48	0	540	688
Avg catch (1972-1990)	8	1	0	8	4	182	1	0	187

Table 2.8. Comparison of egg numbers from replicate samples using two types of Gilson's preservative.

Sample	Vegetation	Gilson's Preservative	
		Mercuric	Non-mercuric
1	Japweed	91217	174573
2	Leafy reds	73578	81684
3	Japweed	473722	420565
4	Japweed	531805	481670
5	Japweed	187600	237944
6	Japweed	1071274	713286
7	Sea grass	384136	343485
8	Stringy reds	149370	135833
9	Stringy reds	226583	188527
10	Leafy reds	321028	216477
11	Leafy reds	392028	354375
12	Leafy reds	403037	263651
13	Sea grass	131086	128034
Mean egg numbers		341266	287700

3. AGE-STRUCTURED MODEL

3.1 INTRODUCTION

An age-structured model, based on the error structure suggested by Fournier and Archibald (1982), has been used to assess B.C. herring stocks since 1982. Ongoing revisions to the model have made it more consistent with the life history of herring and the fisheries which are analyzed. The current version described here uses auxiliary information in the form of spawn survey data, separates catch and age composition data by gear type, and includes availability parameters to estimate partial recruitments to the spawning stock. The model includes realistic assumptions about the form of both measurement and process error. Model parameters are estimated simultaneously using a maximum likelihood method.

3.2 METHODS

The Population Model

Two types of fishing gear are used commonly in B.C. herring fisheries. Seine nets are assumed to be non-selective while gillnets are selective for larger, older fish. Herring fisheries have concentrated primarily on fish which are on, or migrating to the spawning grounds. Therefore, the relative availability of age classes to non-selective gear should be equivalent to the partial recruitment of age classes to the spawning stock. The age-structured model explicitly separates availability (partial recruitment) and gear selectivity. Seine and gillnet fisheries are temporally separate so catch and age-composition are partitioned into fishing periods, separating data for the different gears. Three fishing periods are modelled. The first period encompasses all catch data prior to the spring roe-herring fisheries. This includes reduction fishery catches prior to 1968 and the winter food and bait fisheries since 1970. Most of this catch was taken by seine gear although small amounts were caught with trawl nets (which are also not size selective). The second fishing period includes all seine roe-herring catch and the third period includes all gillnet roe-herring catch.

Let T_{ij} be the total number of fish in age class j at the beginning of season i , and λ_{ij} be the proportion of age j fish which are available to the fishery. Then N_{ij1} , the total number of age class j fish which are available at the start of period 1 in season i is given by

$$N_{ij1} = \lambda_{ij} T_{ij}$$

3.1

To model the fishing process a form of the catch equations which models fishing and natural mortality as continuous processes over time period r , is used:

$$C_{ijr} = \frac{F_{ijr}}{F_{ijr} + M_r} (1 - \exp(-F_{ijr} - M_r)) N_{ijr},$$

and, for $r < p$

$$N_{ijr+1} = N_{ijr} \exp(-F_{ijr} - M_r),$$

where C_{ijr} is the catch of age class j in season i for period r ,
 F_{ijr} is the fishing mortality of age class j in season i for period r ,
 M_r is the natural mortality for period r ,
 N_{ijr} is the number of fish in age class j in season i for period r ,
 p is the number of fishing periods ($p=3$),
 n is the number of seasons ($n=40$),
 k is the number of age classes ($k=10$).

$N_{i+1,j+1,1}$ is defined by equation 3.1 where for $j+1 < k$

$$T_{i+1,j+1} = N_{ijp} \exp(-F_{ijp} - M_p) + T_{ij}(1 - \lambda_{ij}) \exp\left(\sum_r -M_r\right) \quad 3.2$$

In the model the last age class, k , accumulates all fish aged k and older, so for $j+1=k$ equation 3.2 is replaced by

$$T_{i+1,k} = N_{i,k-1,p} \exp(-F_{i,k-1,p} - M_p) + T_{i,k-1}(1 - \lambda_{i,k-1}) \exp\left(\sum_r -M_r\right) + N_{ikp} \exp(-F_{ikp} - M_p) + T_{ik}(1 - \lambda_{ik}) \exp\left(\sum_r -M_r\right).$$

To reduce the number of parameters to be estimated assumptions are made about the availability and mortality. The availabilities are formulated to increase with age and are set to 1 for age 7 and older. For age 4 and older the availabilities are constant between years. Because the proportion of 3-year-olds which are mature appears to vary between years (Haist and Stocker 1985) and some reduction fisheries targetted on immature 2-year-olds the availability for these two age classes is parameterized with annual deviations from the average for the age class ($\bar{\lambda}_j$). Availability for ages 2 and 3 for seasons 1 to $n-1$ (only those

seasons where there is age data) is

$$\lambda_{ij} = \bar{\lambda}_j + d_{ij}.$$

Deviations from average availability are not estimated for ages 2 and 3 in the final year because there is not enough information in the data to estimate these parameters. For ages 4 to 6 and ages 2 and 3 in year n (and seasons where there is no age data)

$$\lambda_{ij} = \bar{\lambda}_j,$$

and for ages 7 and older,

$$\lambda_{ij} = 1.$$

For the selective gillnet fishery, fishing mortality is separated into age selectivity and fishing intensity components. Following Doubleday (1976),

$$\ln(F_{ijr}) = a_{ir} + b_{jr}$$

where a_{ir} represents the general level of fishing mortality due to fishery r in season i , and b_{jr} represents the relative vulnerability of age-class j in fishery r . For ages greater than 7, b_{jr} is fixed at b_{7r} . For non-selective fisheries the model is

$$\ln(F_{ijr}) = a_{ir}.$$

The natural mortality rate is assumed constant over ages and seasons. It is fixed at 0.45 for all assessment regions.

Additional structure is built into the model through the inclusion of annual spawn data (spawn index, I_i) and the assumption of a stock-recruit relationship. Spawning occurs at the end of the season so the number of spawners at age j in season i (G_{ij}) is estimated by

$$G_{ij} = N_{ijp} \exp(-F_{ijp} - M_p)$$

and the reproductive potential (R_i) in season i is

$$R_i = \sum_j w_{ij} G_{ij},$$

where w_{ij} is the average weight at age j in season i . The error in the spawn index observations (I_i) are assumed to be multiplicative so that

$$I_i = q R_i \exp(\xi_i), \quad 3.3$$

where q is a spawn conversion factor and ξ_i is a normally distributed random variable with mean 0 and variance σ_1^2 . A standard Ricker stock-recruit relationship with multiplicative error is assumed,

$$T_{i+1,1} = \alpha R_i \exp(-\beta R_i) \exp(\xi_i), \quad 3.4$$

where ξ_i is a normally distributed random variable with mean 0 and variance σ_2^2 .

For the model described above the parameters to be estimated are:

- T_{il} , for all seasons i ,
- T_{ij} , for age classes 2 to k ,
- $\bar{\lambda}_j$, for age classes 2 to 7,
- d_{ij} , for age classes 2 and 3, for seasons 1 to $n-1$,
- a_{ir} , for all fisheries i, r ,
- b_{jr} , for all selective fisheries (ie. $r=3$),
- α , β , and q .

The $\bar{\lambda}_j$ and d_{ij} are parameterized to constrain the values of λ_{ij} between 0 and 1. The parameters σ_1^2 and σ_2^2 are not estimated in the reconstructions, but are fixed at specified values as discussed later on. The number of parameters for each assessment region are shown in Table 3.1.

The Objective Function

Data input to the stock reconstruction are:

S_{ijr} , the number of sampled fish aged j in season i for period r ,

O_{ir} , the estimated number of fish caught in period r of season i ,

w_{ij} , the estimated weight at age j in year i .

I_i , the estimated spawn index in year i ,

The error structure suggested by Fournier and Archibald (1982) for the observations S_{ijr} and O_{ir} is used:

- 1) The S_{ijr} are obtained from ageing random samples of fish from the catch and there are no ageing errors (i.e. a multinomial sampling distribution).
- 2) The error structure for the estimated number of fish caught (O_{ir}) is log-normal. That is,

$$O_{ir} = C_{ir} \exp(\xi_i),$$

where C_{ir} is the actual number of fish caught in period j in season i ($C_{ir} = \sum_j C_{ijr}$) and the ξ_i are independent normally distributed random variables with mean 0 and variance σ_3^2 .

- 3) The random variables S_{ijr} and O_{ir} are independent.

Given these stochastic assumptions, the log-likelihood function (ignoring the constant term), for the parameters P_{ijr} ($P_{ijr} = C_{ijr}/C_{ir}$), C_{ir} , and σ_3^2 is

$$\sum_{ijr} S_{ijr} \ln(P_{ijr}) - \sum_{ir} \frac{(\ln(O_{ir}) - \ln(C_{ir}))^2}{2\sigma_3^2} - n \ln(\sigma_3) \quad 3.5$$

The assumptions of log-normal measurement error in the observed spawn-actual spawn relationship and log-normal process error in the spawn-recruit relationship introduce the following contributions to the log-likelihood function

$$- \sum_i \frac{(\ln(I_i) - \ln(qR_i))^2}{2\sigma_1^2} \quad 3.6$$

from equation 3.3, and

$$- \sum_i \frac{(\ln(T_{i+1,1}) - \ln(R_i) - \ln(\alpha) + \beta R_i)^2}{2\sigma_2^2} \quad 3.7$$

from equation 3.4. The w_{ij} are assumed to be estimated without error.

The objective function described above (eqn. 3.5 + 3.6 + 3.7) incorporates both measurement (observational) and process (deviations from modelled relationships) error assumptions, with the relative magnitude of the errors related through the variance terms σ_1^2 , σ_2^2 , and σ_3^2 , and the sample sizes $\sum_r S_{ijr}$. Because there is not enough information in the data to estimate the relative error in either the observations or processes, with the exception of scaling the S_{ijr} , the variance terms are not estimated but are held at fixed values. The following variances are assumed:

$$\begin{aligned}\sigma_1^2 &= 0.05, \\ \sigma_2^2 &= 0.25, \\ \sigma_3^2 &= 0.0025.\end{aligned}$$

These correspond to approximately a 4% average error in estimating the total number of fish caught, an 18% average error in spawn index observations, and a 45% average deviation from the spawn-recruit relationship.

The actual number of fish aged, S_{ijr} , could be used in the objective function, however, this may not give a realistic estimate of the precision of the proportion-at-age data. That is, the biological samples obtained may not reflect a homogeneous population. The between-load (ie. samples from different catching vessels) variability in age composition is significantly different between years, and this is related more to the spatial and temporal distribution of the fisheries than to the number of loads sampled or total fish aged. Therefore, the information in the subsamples (between load samples) which are pooled to obtain an estimate of the age composition for a given fishery is used to scale the S_{ijr} .

The theoretical variance of the observed proportion of fish at age j ($\hat{p}_j$) for a random sample of size S is:

$$\sigma_{\hat{p}_j}^2 = \frac{p_j(1-p_j)}{S}$$

where p_j is the true proportion at age j . An estimate of the variance of $\hat{p}_j$ is:

$$s_{\hat{p}_j}^2 = \frac{\sum_m (p_{jm} - \hat{p}_j)^2}{M - 1}$$

where p_{jm} is the proportion at age j in subsample m and M is the number of subsamples. This between-subsample variance results from the variance generated by randomly sampling an individual catch plus the variance in the true proportion at age between vessel catches. Using $\hat{p}_j$ as the best estimate for p_j , the theoretical sample size (S') which would generate the observed variance at age j is:

$$S' = \frac{\hat{p}_j(1 - \hat{p}_j)}{s_{\hat{p}_j}^2}$$

These theoretical sample sizes, calculated from the between sample variance for 4-year-old fish (Appendix Table 1), are used in the objective function.

Stock Forecasts

Forecasts of stock abundance for 1991 are calculated by assuming all natural mortality for the first period will occur prior to the fisheries. The numbers of fish at age prior to the fisheries are then the numbers estimated at the beginning of the 1990/91 season multiplied by survival for the first period and the estimated availability at age. Recruitment is calculated for three scenarios based on estimated numbers-at-age 3 for the 1951-90 time series. Poor, average, and good recruitment are calculated as the mean of the lowest 33%, the mid 33%, and the highest 33% of historic age 3 numbers.

To investigate the bias and variance of the estimated parameters, in particular, current stock estimates and stock forecasts, bootstrap techniques (Efron and Gong 1983) are applied to each of the seven data sets. The bootstrap technique involves resampling the original data set, with replacement, to generate a new data matrix which has the same statistical properties as the original data set. To resample the age composition data a two-stage procedure is used. First random subsamples are selected from the original data set, then individual fish are randomly selected from the subsample. Because there is no information about the error structure of the spawn observations or the total catch estimates these data are resampled under the same assumptions as used in the analytical model. Log-normal errors with a variance of 0.05 and 0.0025 are used for the observed spawn and the observed catch, respectively. The data for each stock grouping were resampled 100 times and reanalysed producing 100 sets of parameter estimates.

Input data used for age-structured model analysis are shown in Appendix Table 1 for all stock groupings. Where no sample data are available, but catches were taken, the

catch is included with an alternate fishery where age-structure data are available. The same spawn index is used as for previous assessments. This index sums the lengths of spawnings multiplied by a width/intensity factor, standardized by section (Hay and Kronlund 1985).

3.3 RESULTS

Results from age-structured model stock reconstructions are shown in Appendix Table 2 for the seven stock assessment regions. Table 3.2 shows bootstrap means and standard deviations for estimated 1990 spawning biomass and forecasts of age 4 and older biomass in 1991.

For past stock assessments, and again in 1990, age-structured model estimates of spawning biomass for the northern west coast of Vancouver Island are substantially higher than those from the escapement model. While the specific reasons for this are unknown, we have identified two factors which may contribute to these differences. The first is that a significant proportion of the reduction fishery catches in Area 25 could have been fish which were destined to spawn in other locations. Tag recovery data, from taggings conducted between 1937 and 1967, showed that only half of the tags recovered in winter fisheries in Area 25 were from fish which had been tagged during the spawning period in Area 25. The remaining recoveries were primarily fish tagged in other areas on the west coast of Vancouver Island (Hourston 1981). This could result in an overestimate of the productivity of this stock. The other factor which could influence the ability of the age-structured model to obtain accurate estimates of recent spawning biomass is the lack of fisheries in recent years. There has been only one fishery in Area 25 in the past six years which limits the information content of data available for analysis. An alternate assessment has been conducted for this region using only data since 1972 (Appendix table 2.8). This limited data set suggests lower spawning abundance than the complete data set and results from this assessment are used for stock forecasts.

The differences between the estimates of 1990 spawning biomass from the stock reconstructions and the bootstrap mean estimates are generally small, with the exception of the northern west coast of Vancouver Island analysis with only post 1972 data (Table 3.2). The differences were tested using a t-test under the null hypothesis that the bootstrap mean was no different than the original estimate. For five of the data sets there was no significant difference between the two estimates. For the Queen Charlotte Islands the probability of no difference was between .05 and .02 and for the northern west coast of Vancouver Island the probability was less than .001. This supports the idea that with the limited fishery and sampling information available, age-structured assessment for this region may be biased.

Confidence limits on stock forecasts were calculated for the 1989 stock assessments using the same bootstrap techniques as this year (Haist and Schweigert 1990).

Current estimates of 1990 pre-fishery biomass are compared with these forecast confidence intervals (95%) in Table 3.3. Results are presented for only five of the assessment regions because different stock definitions were used in the 1989 assessment for the two other stocks. For four of the five assessment regions the 1990 estimate of age 4+ biomass is within the forecast 95% confidence interval. Similar comparisons of forecast confidence limits with following year estimates of abundance, conducted over the past two years, showed that 6 of 14 estimates were outside the confidence region, which is significantly higher than the expected occurrence of 1 in 20. Additional work is required to assess whether the bootstrap method provides consistent estimates of confidence limits.

Table 3.1. Number of parameters for age-structured analysis for seven assessment regions.

For all assessment regions:	T_{il}	40	
	T_{li}	9	
	$\bar{\lambda}_j$	7	
	b_{jr}	7	
	α, β, q	3	
	Total	66	
Stock Specific:	a_{ir}	d_{ij}	Total
Queen Charlotte Islands	49	68	184
Prince Rupert District	67	78	212
Central Coast	58	76	201
N. Strait of Georgia	72	78	217
S. Strait of Georgia	64	78	209
S. W. Coast Vancouver Is.	50	70	187
N. W. Coast Vancouver Is.			
- all years data	42	62	171
- 1972-90 data only	29	36	111

Table 3.2. Bootstrap estimates of 1990 spawning biomass (tonnes) and forecast 1991 age 4, age 4+, and age 5+ biomass (tonnes) for herring stock assessment regions. The estimates for the original data sets and bootstrap means and standard deviations are also presented.

	1990 Spawning Biomass	1991 Biomass Forecast		
		Age 4	Age 4+	Age 5+
Queen Charlotte Islands	23,918		21,791	
bootstrap - mean	24,656	2,494	22,401	19,906
- st. dev.	3,350	413	2,894	2,573
Prince Rupert District	56,708		54,359	
bootstrap - mean	57,174	9,948	54,774	44,826
- st. dev.	6,217	1,352	5,957	4,923
Central Coast	38,848		31,659	
bootstrap - mean	39,403	1,957	32,119	30,161
- st. dev.	3,872	269	3,069	2,906
Strait of Georgia				
Northern Stock	49,585		47,419	
bootstrap - mean	50,245	30,413	47,933	17,520
- st. dev.	7,228	4,569	6,828	2,643
Southern Stock	15,768		14,569	
bootstrap - mean	15,362	10,841	14,238	3,397
- st. dev.	2,760	1,961	2,501	665
W. Coast Vancouver Island				
Southern Stock	18,552		15,203	
bootstrap - mean	18,145	4,660	14,987	10,326
- st. dev.	2,774	665	2,203	1,608
Northern Stock				
(data for all years)	21,302		16,058	
bootstrap - mean	21,419	3,932	16,300	12,367
- st. dev.	3,269	1,247	2,619	1,688
(1972-90 data only)	17,880		13,642	
bootstrap - mean	15,024	496	11,096	10,589
- st. dev.	2,986	1099	2,238	1,882

Table 3.3. Comparison of forecast and estimated 1990 age 4, age 4+, and age 5+ biomass (tonnes) for herring stock assessment regions. The forecast 95% confidence intervals are from bootstrap analyses from the 1989 assessment. The estimated values are from the 1990 age-structured model analyses. Current estimates which are outside the forecast confidence limits are marked.*

Stock Assessment Region	1989 Bootstrap Forecast	1990 Estimate
Prince Rupert District		
age 4	7610 - 13389	12445
age 4+	40437 - 61978	53493
age 5+	32260 - 49155	41048
Central Coast		
age 4	1259 - 2470	2012
age 4+	30369 - 52106	45557
age 5+	29006 - 49739	43546
Northern Strait of Georgia		
age 4	5377 - 10186	7028
age 4+	22147 - 41472	26048
age 5+	16440 - 31615	19020
Southern Strait of Georgia		
age 4	915 - 1954	1714
age 4+	6227 - 10060	7800
age 5+	5169 - 8246	6086
Southern west coast Vancouver Is.		
age 4	2175 - 4742	3327
age 4+	11059 - 24042	22790
age 5+	8769 - 19412	19463*

4. SPAWN TRENDS, STOCK FORECASTS AND POTENTIAL CATCH

4.1 SPAWN TRENDS

Estimates of spawning stock biomass over the period 1972 to 1990 from the age-structured and escapement models are shown in Figures 4.1 and 4.2 for the seven major assessment regions.

For the Queen Charlotte Islands region the two models indicate similar trends in spawning stock biomass. However, the age-structured model suggests much higher peaks in abundance in the mid 1970's and the early 1980's resulting from good recruitment of the 1971, 1972 and 1977 year classes. Both models suggest a slight decrease in abundance from 1989 to 1990. The above average 1985 year class is dominant, with 5-year olds comprising 60% of the stock in 1990. The estimates of 1990 spawning biomass are 23,900 and 24,200 tonnes from age-structured and escapement model analyses, respectively.

Trends in spawn abundance from the two assessment models do not track each other very closely for the Prince Rupert Assessment region (Fig. 4.1). Age-structured model estimates of abundance are consistently higher than those from the escapement model, and for the past two years in particular the two models indicate divergent stock trends. A potential source of bias in the age-structured model could be inconsistency in the parameterization of gillnet selectivity. This is parameterized as an age-dependent process while there has been a decrease in selectivity of younger fish (i.e., age 4 to 6) in recent years as size-at-age has decreased. This inconsistency could lead to overestimation of stock size. A modification of the age-structured model to change gillnet selectivity from an age-selective to size-selective process is required to assess the impact of size-at-age trends on gear selectivity, and ultimately, stock estimates. Until this modification is made and evaluated, we suggest not using the age-structured model stock estimates. The escapement model estimate of 19,400 tonnes of spawners in 1990 represents an increase in stock size over the 1989 level. However, this apparent increase is also an anomaly as it implies that the abundance of repeat spawners in 1990 was greater than the escapement in 1989.

Estimates of spawning stock biomass for the central coast assessment region follow similar trends for both models (Fig. 4.1). Both models estimate spawn abundances at near historical high levels over the past three years. Currently, the strong 1985 year class is dominant with 5-year olds comprising 73% of the stock. The 1990 spawning stock biomass estimates are 38,800 and 42,300 tonnes from age-structured and escapement model analyses, respectively.

For the two Strait of Georgia assessment regions the spawning trends estimated by the two models are not very similar, with the escapement model suggesting much greater fluctuations in abundance. However, estimates of 1990 spawning biomass are similar for the

two models. Both models estimate a significant increase in biomass from 1989 to 1990 for the southern stock, with 1990 estimates of 15,800 and 13,200 tonnes. Age-structured model analysis suggests a continual increase in spawning abundance since 1984 for the northern assessment region with a 1990 estimate of 49,600 tonnes. The escapement model estimate of 45,700 tonnes is lower than some of the estimated spawning biomasses during the 1980's. The 1987 year-class, which recruited to the fishery as 3-yr olds in 1990, is dominant in both assessment regions. This year class comprised 56% of the northern stock and 59% of the southern stock.

The spawning biomass for the southern west coast of Vancouver Island stock follow similar trends for the two assessment models through most of the time series, however there are periods where estimates from the two models are quite different (Fig 4.2). Both models suggest a decrease in spawn abundance from 1989 to 1990, with the age-structured model indicating a more substantial decline. The escapement model estimate for 1990 spawning biomass is 29,600 tonnes while the age-structured model estimate is 18,600 tonnes. The 1985 year class is dominant in this stock with 5-yr olds comprising 48% of the sampled fish while 3-yr olds comprised 27% of the stock.

As in past assessments, the age-structured model indicates a much greater increase in spawn abundance since the mid 1980's relative to the increase suggested by the escapement model for the northern west coast Vancouver Island assessment region. However, as suggested in Section 3, the age-structured model may be producing biased estimates for this region. The 1990 spawning biomass estimates are 8,300 tonnes and 17,900 tonnes from the escapement and age-structured models.

4.2 STOCK FORECASTS AND POTENTIAL CATCH

We recommend catch levels at 20% of the forecast stock biomass for those stocks that are well above CUTOFF. The 20% harvest rate is based on an analysis of stock dynamics which indicates this level will stabilize both catch and spawning biomass while foregoing minimum yield over the long term. A fixed escapement policy would theoretically produce higher yields and spawning stock stability but is not attainable at the operational level. For those stocks which are marginally above CUTOFF we recommend the following reduced catch level:

$$\text{Catch} = \text{Weighted Run} - \text{CUTOFF}.$$

This will provide for smaller fisheries for areas where the 20% harvest rate would bring the escapement down to levels below the CUTOFF.

CUTOFF levels are established at one-fourth the unfished average biomass. For the seven stock assessment regions the CUTOFF levels are:

Queen Charlotte Islands	11,700 t.
Prince Rupert District	12,100 t.
Central Coast	10,600 t.
Strait of Georgia	22,100 t.
W.C. Vancouver Is.-south	15,100 t.
W.C. Vancouver Is.-north	5,200 t.

The CUTOFF level for the Queen Charlotte Islands represents a change due to the revision in the stock assessment region which now includes Louscoone and Cumshewa Inlets. The revised CUTOFF is based on the estimated unfished average biomass as determined using stock productivity parameters from age-structured analysis for the revised assessment region. However, a similar analysis for the northern west coast of Vancouver Island did not provide a consistent estimate of the unfished biomass level. The revised CUTOFF for this region is therefore based on the proportion of the total Area 25 through Area 27 spawn which occurred in Area 25 over the 1951-90 time period, and the previous CUTOFF level which had been estimated for the Area 25-27 region.

To provide an overall stock forecast we assigned subjective probabilities to the two assessment models. The age-structured model provides consistent estimates of abundance, and it would be expected that estimates from this model are relatively precise. However, it is not possible to evaluate the accuracy of this model other than by comparison of estimates with independent estimates of absolute abundance. The escapement model incorporates diving survey information on most major spawns in 1990, and we feel these direct estimates of egg deposition provide a reasonably accurate estimate of current stock size, although the estimates are probably not very precise. Hence, we used equal probabilities for the two models in most assessment regions. An exception to this is for the northern west coast of Vancouver Island where age-structured analysis appears to be biased. Consequently, we use a 80:20 weighting in favour of the escapement model for this area. In addition, we suggest not weighting the age-structured model assessment of the Prince Rupert District stocks in the weighted run forecast.

The assigned probabilities were used to weight the forecast runs obtained from each method to provide a single "weighted run" for each of the stock groupings (Table 4.1).

The forecast weighted run size to the Queen Charlotte Islands in 1991 is 23,200 tonnes assuming average recruitment. This is significantly lower than the 1990 forecast and yields a potential catch of 4,640 tonnes.

Because of the uncertainty regarding the application of the age-structured model for the Prince Rupert District we forecast a run size of 19,400 tonnes based solely on the escapement model estimate. The forecast run is comparable to last year and although significantly decreased from prior years is still well above the CUTOFF of 12,100 tonnes.

Assuming an average recruitment level, a catch of 3,880 tonnes should be available for the Prince Rupert District in 1991.

The weighted forecast for the central coast with average recruitment is 38,200 tonnes. The recommended catch for this region is 7,640 tonnes. The 1991 forecast is down slightly from levels of the previous two years because the strong 1985 year class is ageing and there is no indication of significant recruitment from the two subsequent year-classes.

The weighted forecast run to the northern Strait of Georgia in 1991 is 53,700 tonnes, and to the southern Strait of Georgia 16,100 tonnes. An average recruitment assumption would yield potential catches of 10,740 and 3,220 tonnes, respectively. Both assessment models indicate increases in stock levels for both assessment regions and stock forecasts are slightly higher than they were for 1990.

The forecasted run to the southern west coast of Vancouver Island is 25,800 tonnes for an allowable catch of 5,160 tonnes. The forecast for the northern west coast of Vancouver Island, with a lower weighting on the age-structured model, is 10,000 tonnes for a recommended catch of 2,000 tonnes.

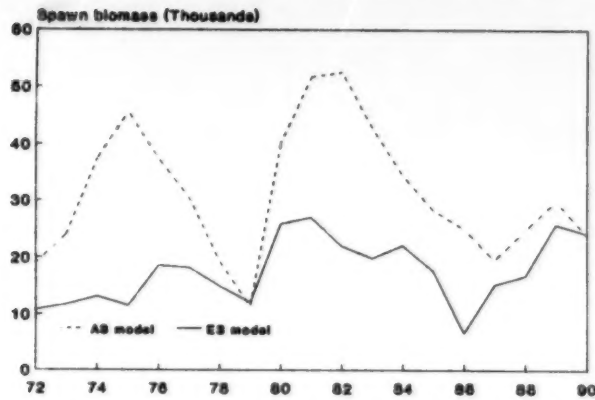
The catch levels suggested in this summary are based purely on biological considerations, reflecting the best biological analyses given the available data bases. Management of the various fisheries has practical constraints not considered in this report. As well, there are economic considerations which are beyond the scope of our analysis. Hence, the quotas ultimately adopted by DFO may differ from those suggested herein.

Table 4.1. Summary of 1991 forecast stock biomass (thousands of tonnes) from age-structured and escapement models and weighted runs for poor, average, and good recruitment levels.

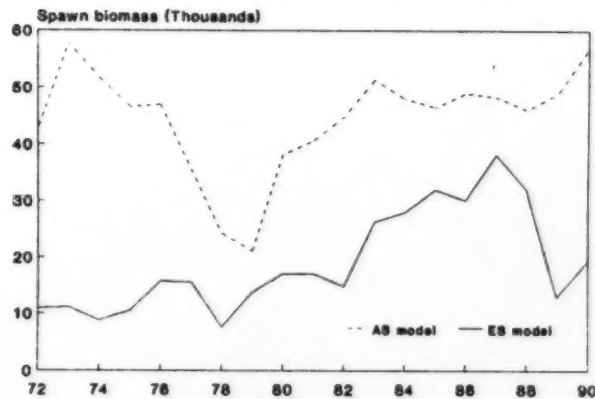
Stock Assessment Regions	AGE-STRUCTURED MODEL					ESCAPEMENT MODEL					WEIGHTED RESULTS				
	Age		Recruitment Level			Age		Recruitment Level			Relative		Recruitment Level		
	4+		Poor	Avg.	Good	4+		Poor	Avg.	Good	Weight	Poor	Avg.	Good	
Queen Charlotte Islands	21.8	23.0	25.6	33.0	17.4	18.3	20.9	26.4	50:50	20.6	23.2	29.7			
Prince Rupert District	54.4	56.6	60.7	73.5	14.5	16.0	19.4	27.8	0:100	16.0	19.4	27.8			
Central Coast	31.7	34.7	38.4	49.1	30.9	33.5	38.0	38.9	50:50	34.1	38.2	44.0			
Strait of Georgia - northern stock	47.4	52.1	57.1	67.5	35.3	43.0	50.3	59.5	50:50	47.5	53.7	63.5			
southern stock*	14.6	16.1	17.8	21.5	9.6	12.7	14.4	15.9	50:50	14.4	16.1	18.7			
W.C. Vancouver Island - southern stock	15.2	19.1	22.8	34.3	21.3	24.8	28.9	35.7	50:50	21.9	25.8	35.0			
northern stock	13.6	15.1	16.2	21.7	5.8	6.6	8.5	13.4	20:80	8.3	10.0	15.1			

*Recruitment estimates based on data from roe fishery only.

Queen Charlotte Islands



Prince Rupert District



Central Coast

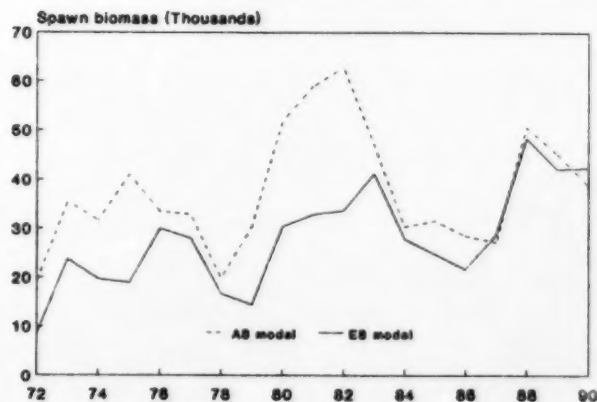
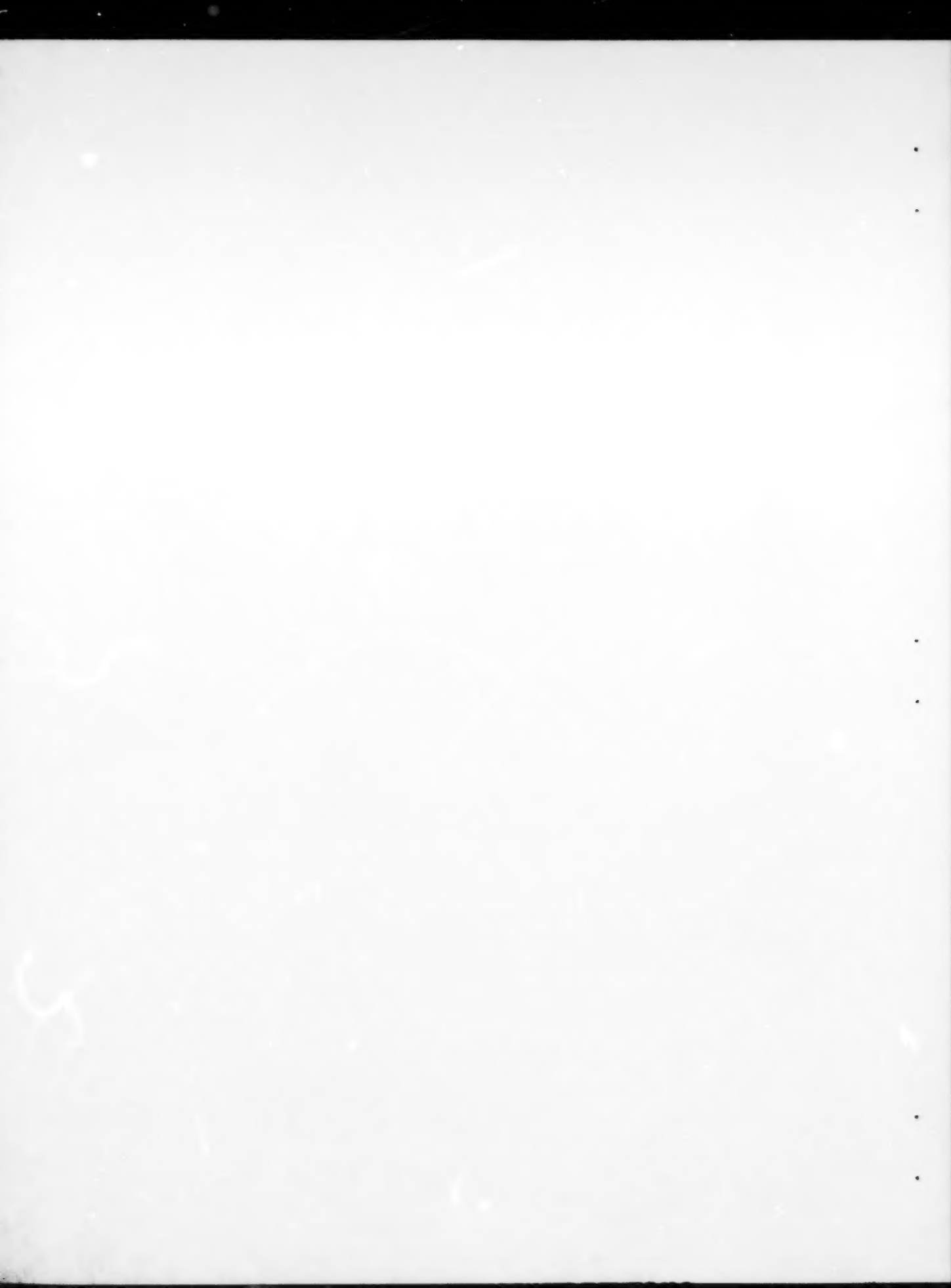
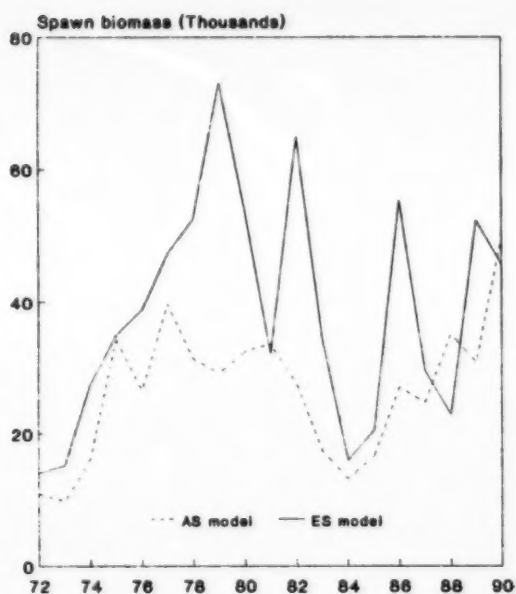


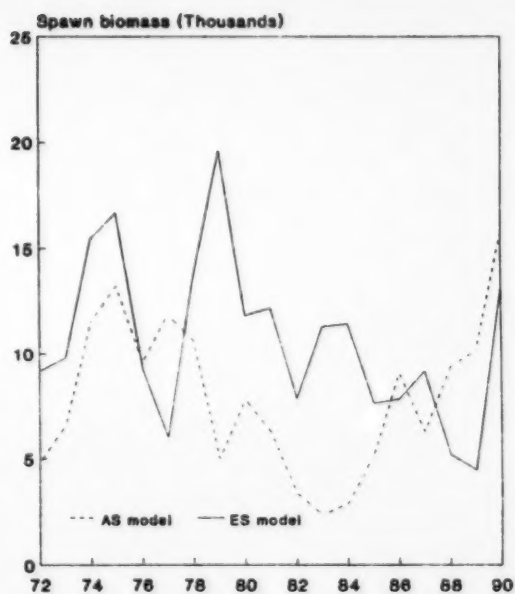
Fig. 4.1 Estimates of spawning stock biomass (1972-90) from age-structured and escapement model analyses for northern B.C. herring stock assessment regions.



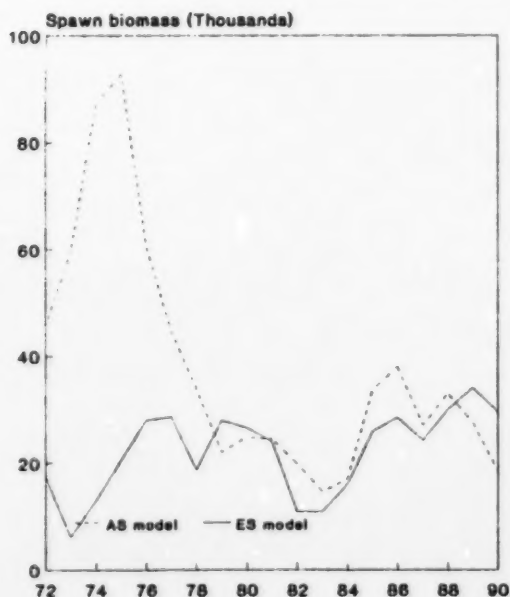
Strait of Georgia - north



Strait of Georgia - south



W. coast Vancouver Is. - south



W. coast Vancouver Is. - north

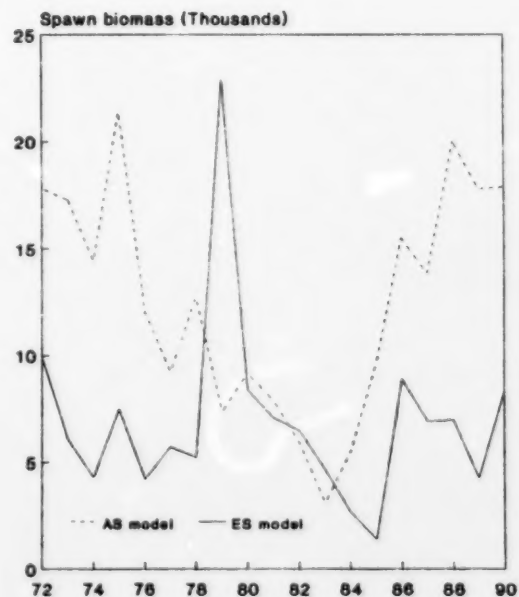


Fig. 4.2 Estimates of spawning stock biomass (1972-90) from age-structured and escapement model analyses for southern B.C. herring stock assessment regions.

6. REFERENCES

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Appendix table 1.1. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the Queen Charlotte Islands stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	PERCENT AT AGE										NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10 ⁶)
		1	2	3	4	5	6	7	8	9	10			
1950/51	REDUCTION	0.0	0.1	15.3	52.9	15.3	11.5	4.2	0.6	0.1	0.0	1476	1544	317.44
1951/52	REDUCTION	1.2	16.9	21.5	33.8	21.3	4.1	1.1	0.1	0.0	0.0	2251	165	1136.50
1953/54	REDUCTION	0.1	3.0	29.0	21.3	33.6	10.2	1.9	0.7	0.2	0.1	0*	25	231.77
1954/55	REDUCTION	0.0	8.7	14.1	39.4	18.1	14.8	4.4	0.3	0.1	0.1	0*	25	52.94
1955/56	REDUCTION	0.0	0.1	16.0	9.6	62.2	8.4	2.7	0.7	0.0	0.1	1348	681	6551.83
1956/57	REDUCTION	0.1	20.7	24.1	15.7	9.6	26.7	2.4	0.4	0.1	0.0	4740	2177	2092.34
1957/58	REDUCTION	0.0	81.9	16.4	1.2	0.2	0.1	0.1	0.0	0.0	0.0	2838	514	2146.22
1958/59	REDUCTION	0.0	1.1	63.2	28.4	7.4	0.0	0.0	0.0	0.0	0.0	95	6	735.74
1960/61	REDUCTION	0.0	4.2	32.6	36.0	24.8	1.3	0.4	0.2	0.4	0.0	0*	25	59.00
1961/62	REDUCTION	0.0	3.0	37.6	41.4	9.6	6.5	1.6	0.2	0.0	0.0	428	170	693.85
1962/63	REDUCTION	0.0	0.4	50.0	27.1	18.2	2.1	2.0	0.0	0.1	0.1	804	411	1342.32
1963/64	REDUCTION	0.0	0.9	15.3	59.5	17.8	5.3	1.1	0.0	0.0	0.0	528	297	2515.06
1964/65	REDUCTION	0.0	1.6	79.8	11.0	4.4	2.1	0.9	0.2	0.0	0.0	1053	165	3424.55
1965/66	REDUCTION	1.7	18.0	32.2	16.1	10.2	7.3	5.8	4.8	2.0	1.7	0*	25	213.13
1966/67	REDUCTION	0.0	0.9	67.3	26.5	2.7	2.7	0.0	0.0	0.0	0.0	0*	25	18.83
1967/68	REDUCTION	0.8	29.7	50.2	17.1	2.2	0.0	0.0	0.0	0.0	0.0	0*	25	8.48
1971/72	ROE-SN	0.0	3.0	32.6	38.3	16.0	6.1	2.4	0.9	0.4	0.1	1184	94	276.24 ^u
1972/73	ROE-SN	0.0	0.2	40.6	21.6	27.3	8.0	1.7	0.8	0.0	0.0	1726	914	524.51
1973/74	ROE-SN	0.0	0.1	30.5	40.4	17.7	9.1	1.9	0.3	0.1	0.0	1617	185	482.78
	ROE-GN	0.0	0.0	5.7	48.4	25.5	16.6	3.2	0.0	0.0	0.6	157	25	8.24
1974/75	ROE-SN	0.0	0.6	25.3	34.2	27.9	9.5	1.9	0.4	0.1	0.0	6010	655	587.13 ^u
	ROE-GN	0.0	0.0	0.0	22.5	40.0	30.0	5.0	2.5	0.0	0.0	40	40	6.19
1975/76	ROE-SN	0.0	0.4	2.8	37.3	29.4	22.7	6.3	1.0	0.1	0.0	4170	247	813.57 ^u
	ROE-GN	0.0	0.0	0.0	0.8	21.8	60.9	14.3	2.3	0.0	0.0	133	186	91.86
1976/77	ROE-SN	0.0	0.1	19.6	8.0	29.4	23.0	15.1	4.5	0.4	0.0	3220	1113	801.25 ^u
1977/78	ROE-SN	0.0	0.2	26.2	17.3	9.5	26.2	14.1	5.3	1.0	0.3	1234	1932	620.46
	ROE-GN	0.0	0.0	0.6	4.8	11.5	19.4	39.4	20.0	3.6	0.6	165	126	129.55
1978/79	ROE-SN	0.0	5.6	4.4	31.6	18.7	21.3	15.1	2.8	0.4	0.1	1020	441	387.56 ^u
	ROE-GN	0.0	0.0	0.0	25.1	25.1	25.1	20.1	3.5	0.5	0.5	199	65	128.20
1979/80	ROE-SN	0.0	0.5	83.2	4.5	5.4	2.8	1.9	1.2	0.6	0.1	3390	2427	222.15
	ROE-GN	0.0	0.0	3.7	4.5	40.1	20.8	22.3	6.9	1.6	0.1	938	1028	74.53
1980/81	ROE-SN	0.0	0.2	3.5	85.0	5.4	3.1	1.8	0.7	0.2	0.1	4943	489	331.92 ^u
	ROE-GN	0.0	0.0	0.2	74.8	8.3	9.4	4.9	1.9	0.6	0.0	905	339	121.41
1981/82	ROE-SN	0.0	0.8	4.5	4.4	84.6	2.4	1.6	0.9	0.5	0.1	3591	1725	185.38 ^u
	ROE-GN	0.0	0.0	0.2	3.4	88.2	3.4	2.7	1.1	0.8	0.2	526	341	99.20
1982/83	ROE-SN	0.0	4.9	5.2	3.5	6.9	72.9	3.9	1.6	0.9	0.3	1968	1609	317.79 ^u
	ROE-GN	0.0	0.0	0.0	1.3	2.8	89.0	3.1	2.5	0.7	0.5	747	637	58.91
1983/84	OTHER	0.0	5.9	36.6	2.2	4.3	8.6	39.2	2.2	0.5	0.5	186	186	16.18
	ROE-SN	0.0	2.1	35.3	4.9	2.8	10.5	42.8	1.0	0.4	0.2	3104	1554	312.33
	ROE-GN	0.0	0.0	2.8	1.3	4.6	9.0	80.1	1.8	0.3	0.3	391	427	34.59
1984/85	ROE-SN	0.0	1.3	14.9	31.8	4.0	4.5	11.4	31.5	0.4	0.1	3556	699	311.61 ^u
	ROE-GN	0.0	0.0	0.0	15.3	2.1	4.2	11.1	66.7	0.7	0.0	144	83	85.78
1985/86	ROE-SN	0.0	0.2	2.8	22.0	40.2	4.0	3.3	8.0	19.1	0.3	4733	2821	157.73
	ROE-GN	0.0	0.0	0.0	11.9	50.6	5.4	5.2	10.4	16.0	0.5	405	383	55.79
1986/87	ROE-SN	0.0	1.7	10.4	5.9	24.4	37.8	3.8	4.3	5.8	5.9	3281	1144	131.07 ^u
1987/88	ROE-SN	0.0	3.6	51.0	7.5	4.8	11.8	14.9	1.4	1.7	3.4	1676	575	2.56 ^u
1988/89	ROE-SN	0.0	2.3	17.5	66.3	4.0	1.6	3.9	2.8	0.6	1.0	3563	199	121.30 ^u
1989/90	ROE-SN	0.0	0.2	9.7	18.2	60.0	3.9	1.8	3.8	1.7	0.7	5055	409	411.56
	ROE-GN	0.0	0.0	0.5	8.3	43.6	10.2	8.5	17.1	8.5	3.2	433	397	75.32
		AVERAGE WEIGHT AT AGE (gms)												
	FISHERY	1	2	3	4	5	6	7	8	9	10			
	REDUCTION	11.7	52.0	84.4	106.6	125.9	147.7	156.8	172.1	147.3	183.5			
	ROE-SN	0.0	66.2	98.3	126.3	150.8	171.7	187.7	201.6	214.5	214.1			
	ROE-GN	0.0	0.0	119.8	141.9	153.5	171.1	180.2	192.8	190.8	198.0			
	OTHER	11.7	61.1	93.7	119.7	142.8	165.0	179.0	194.9	205.2	208.7			

* - Age composition from published reports.

- - No seine roe fishery in this season. Age composition from pre-fishery charter samples only.

^u - includes catch from "other" fisheries

^u - includes catch from seine roe fisheries

^u - includes catch from gillnet fisheries

Appendix table 1.2. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the Prince Rupert District stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	1	2	3	4	5	6	7	8	9	10	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10 ³)
1950/51	REDUCTION	0.0	4.3	18.2	58.5	10.4	5.6	2.6	0.3	0.0	0.0	4684	2202	4954.74
1951/52	REDUCTION	0.1	4.8	8.8	33.7	45.2	6.1	1.0	0.3	0.0	0.0	5925	2500	4392.63
1952/53	REDUCTION	0.0	1.2	38.1	23.0	25.4	11.1	1.0	0.1	0.0	0.0	1419	752	173.50
1953/54	REDUCTION	0.0	2.1	28.4	29.1	24.0	13.2	2.6	0.6	0.0	0.0	2656	891	2522.89
1954/55	REDUCTION	0.0	2.7	4.9	70.3	15.6	5.2	1.1	0.2	0.0	0.0	1131	467	1698.85
1955/56	REDUCTION	0.0	10.0	58.1	9.5	19.0	2.6	0.5	0.2	0.1	0.0	1683	555	1218.10
1956/57	REDUCTION	0.0	11.5	17.8	39.8	13.2	16.0	1.4	0.3	0.0	0.0	3491	515	2827.98
1957/58	REDUCTION	0.0	45.8	30.2	8.0	11.8	1.8	2.4	0.0	0.0	0.0	847	123	644.16
1958/59	REDUCTION	0.0	3.1	56.7	20.9	5.8	9.9	1.7	1.9	0.1	0.0	1741	349	1037.09
1959/60	REDUCTION	0.0	49.1	6.3	28.2	8.9	4.1	2.5	0.7	0.2	0.0	4206	337	2451.31
1960/61	REDUCTION	0.0	9.7	58.3	7.3	18.0	4.3	1.6	0.6	0.1	0.0	4300	763	4815.52
1961/62	REDUCTION	0.0	3.0	30.3	44.7	6.9	9.9	3.4	0.9	0.5	0.3	1845	752	2476.36
1962/63	REDUCTION	0.0	39.3	13.3	18.2	22.0	3.6	3.0	0.5	0.1	0.1	3415	433	4788.66
1963/64	REDUCTION	0.0	3.7	64.9	10.1	10.9	8.9	0.7	0.6	0.1	0.0	3400	1914	3555.87
1964/65	REDUCTION	0.0	6.0	13.6	51.0	8.5	11.0	8.5	1.0	0.3	0.1	3360	459	3649.12
1965/66	REDUCTION	0.0	0.0	5.3	21.4	23.4	16.3	19.1	9.7	3.2	1.6	435	59	1071.96
1966/67	REDUCTION	0.9	56.7	31.9	5.3	1.9	2.7	0.4	0.2	0.0	0.0	0*	25	1225.88
1967/68	REDUCTION	3.2	33.7	38.5	18.8	4.4	0.7	0.3	0.1	0.3	0.0	0*	25	281.72
1968/69	OTHER	1.3	29.7	44.5	20.3	3.8	0.2	0.2	0.0	0.0	0.0	0*	25	69.79
1969/70	OTHER	0.7	18.5	62.4	15.0	3.1	0.0	0.1	0.1	0.0	0.0	0*	25	184.71
1970/71	OTHER	0.0	6.5	50.4	29.3	8.0	4.3	0.8	0.5	0.2	0.0	601	38	413.67
1971/72	ROE-SN	0.0	0.0	5.3	17.9	64.4	5.9	3.8	2.4	0.1	0.1	714	209	278.66 ^h
1972/73	OTHER	0.0	22.9	47.7	7.8	13.1	4.6	2.6	1.3	0.0	0.0	153	14	35.70
	ROE-SN	0.0	0.3	33.0	4.4	30.4	26.6	3.4	1.3	0.8	0.0	797	662	94.37
1973/74	ROE-SN	0.0	0.2	17.9	53.2	7.4	16.5	4.4	0.3	0.2	0.0	632	121	174.36 ^h
	ROE-GN	0.0	0.0	1.0	39.4	21.2	34.6	2.9	1.0	0.0	0.0	104	83	90.07
1974/75	OTHER	0.0	1.2	10.5	15.1	43.0	14.0	11.6	2.3	2.3	0.0	86	86	14.18
	ROE-SN	0.3	1.3	9.4	22.1	43.0	11.1	9.6	2.5	0.6	0.2	3084	769	116.58
	ROE-GN	0.0	0.0	0.0	31.9	59.6	8.5	0.0	0.0	0.0	0.0	47	47	0.76
1975/76	OTHER	0.0	0.0	4.9	6.8	9.9	16.7	17.9	35.2	8.6	0.0	162	1661	30.99
	ROE-SN	0.0	0.0	0.8	6.9	31.7	50.1	7.3	2.4	0.8	0.0	713	654	204.01
	ROE-GN	0.0	0.0	0.0	15.8	57.9	22.8	3.5	0.0	0.0	0.0	57	57	17.93
1976/77	OTHER	0.0	0.4	23.5	15.7	22.9	16.6	10.8	7.4	2.3	0.4	511	276	61.55
	ROE-SN	0.0	0.1	16.0	3.7	22.7	37.8	15.0	3.3	0.9	0.5	1310	1344	370.40
	ROE-GN	0.0	0.0	1.1	2.1	19.9	54.1	14.6	6.8	1.4	0.0	281	1104	89.48
1977/78	OTHER	0.0	1.3	9.6	27.8	18.2	18.1	14.6	6.9	2.4	1.0	982	124	238.36
	ROE-SN	0.0	1.1	11.7	32.8	9.6	21.1	20.4	2.4	0.6	0.3	795	131	136.94
	ROE-GN	0.0	0.0	0.0	20.5	6.0	32.5	33.1	6.6	1.3	0.0	151	37	181.42
1978/79	OTHER	0.0	1.8	9.3	9.8	25.9	17.8	16.2	9.5	5.7	4.0	1435	856	118.66
	ROE-SN	0.0	2.7	18.2	11.5	29.2	11.5	18.3	6.5	1.4	0.8	958	1475	84.40
	ROE-GN	0.0	1.1	1.1	8.0	41.4	15.7	22.2	8.0	1.9	0.4	261	255	74.00
1979/80	OTHER	0.0	1.1	61.2	6.5	7.9	8.2	6.5	4.9	2.1	1.6	1161	560	66.18
	ROE-SN	0.0	0.6	77.9	7.3	5.1	3.8	3.5	1.3	0.4	0.1	2811	535	171.81
	ROE-GN	0.0	0.0	3.4	8.7	31.2	22.3	21.1	9.1	3.4	0.6	493	915	63.73
1980/81	OTHER	0.0	1.0	7.4	54.6	9.3	10.2	9.3	4.3	2.3	1.5	6524	1129	137.14
	ROE-SN	0.0	0.5	11.2	81.2	3.3	1.7	1.5	0.4	0.2	0.1	3238	1059	106.00
	ROE-GN	0.0	0.0	0.5	38.9	15.5	23.0	14.8	5.6	1.9	0.0	427	557	23.77
1981/82	OTHER	0.0	1.5	11.5	20.5	41.1	10.5	6.6	5.0	2.1	1.1	2669	555	138.82
	ROE-SN	0.0	2.7	18.8	7.4	66.3	2.8	1.4	0.4	0.2	0.0	1544	576	16.50
1982/83	ROE-SN	0.0	1.4	20.8	17.7	5.3	49.2	3.7	1.1	0.6	0.2	4583	1448	1.00 ⁻
1983/84	OTHER	0.0	2.8	36.2	15.7	13.9	9.8	16.4	2.8	1.1	1.4	654	303	23.68
	ROE-SN	0.0	0.5	35.5	14.4	10.3	14.4	23.6	1.0	0.2	0.1	2837	618	159.00
	ROE-GN	0.0	0.0	1.0	2.0	12.9	21.4	57.4	3.4	1.2	0.8	505	961	127.31
1984/85	OTHER	0.0	15.4	8.2	25.8	28.2	11.7	5.4	4.1	0.8	0.3	631	45	28.24
	ROE-SN	0.0	0.2	7.8	54.7	11.9	6.4	10.6	8.2	0.1	0.1	3664	969	278.16
	ROE-GN	0.0	0.0	0.4	16.4	14.9	15.8	21.8	29.8	0.4	0.5	550	543	235.00
1985/86	OTHER	0.0	11.7	9.9	8.0	21.3	18.6	11.7	6.6	6.9	5.2	767	512	25.39
	ROE-SN	0.0	1.8	13.8	9.4	46.3	10.8	5.3	7.1	5.5	0.1	5655	4566	277.60
	ROE-GN	0.0	0.0	0.4	4.3	53.8	19.0	8.7	7.8	5.7	0.2	1274	558	311.02
1986/87	ROE-SN	0.0	0.9	38.6	10.2	6.9	29.9	5.9	3.5	2.9	1.2	4731	4068	187.95 ^h
	ROE-GN	0.0	0.0	0.6	3.0	6.9	55.3	16.1	8.8	6.0	3.4	1761	819	270.57
1987/88	ROE-SN	0.0	0.5	30.9	39.0	5.9	8.4	11.6	1.9	1.4	0.4	4222	2993	353.56 ^h
	ROE-GN	0.0	0.0	0.4	6.5	7.2	21.5	44.8	11.7	5.1	2.8	710	421	276.81
1988/89	ROE-SN	0.0	0.6	21.7	36.1	27.7	4.9	4.5	3.6	0.6	0.3	3616	1265	357.83 ^h
	ROE-GN	0.0	0.0	0.0	4.6	30.5	13.7	23.5	21.8	3.4	2.5	476	432	317.93
1989/90	ROE-SN	0.0	0.7	18.2	22.6	20.5	4.0	3.3	2.2	0.4	0.4	5068	3572	150.28
	ROE-GN	0.0	0.0	0.0	6.3	21.3	42.5	10.3	11.6	6.1	2.0	544	180	154.63

FISHERY	1	2	3	4	5	6	7	8	9	10
REDUCTION	21.8	43.9	79.3	107.9	128.2	146.1	163.1	173.5	188.7	206.8
ROE-SN	8.6	53.1	84.1	113.6	137.3	156.2	170.4	184.0	192.8	204.8
ROE-GN	0.0	90.3	115.5	136.1	147.0	160.7	168.2	175.7	185.9	191.5
OTHER	17.4	47.0	80.9	110.0	132.5	150.7	165.9	178.0	187.6	203.0

Appendix table 1.3. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the central coast stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	1	2	3	4	PERCENT AT AGE					10	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10 ⁶)
						5	6	7	8	9				
1950/51	REDUCTION	0.0	2.4	28.5	50.6	12.0	5.1	1.2	0.1	0.0	0.0	5318	2484	3905.26
1951/52	REDUCTION	1.1	5.1	19.9	29.7	37.7	4.4	1.5	0.4	0.0	0.0	5214	1352	2954.66
1952/53	REDUCTION	0.4	9.3	28.0	23.9	26.5	10.1	1.3	0.4	0.0	0.0	2939	537	73.85
1953/54	REDUCTION	0.1	3.9	69.6	20.2	4.6	1.3	0.2	0.0	0.1	0.0	3191	477	3478.53
1954/55	REDUCTION	0.3	6.6	7.7	74.4	9.1	1.5	0.4	0.0	0.0	0.0	2350	164	1237.50
1955/56	REDUCTION	0.0	16.9	13.6	9.2	57.0	2.9	0.3	0.0	0.0	0.0	5054	1351	4136.15
1956/57	REDUCTION	0.0	16.7	50.7	10.8	6.2	14.8	0.7	0.0	0.0	0.0	4688	1703	2635.45
1957/58	REDUCTION	0.0	23.5	61.4	12.7	1.3	0.6	0.6	0.0	0.0	0.0	3743	847	1445.86
1958/59	REDUCTION	0.4	3.8	49.3	36.7	8.1	0.8	0.4	0.4	0.0	0.0	4996	1337	3305.21
1959/60	REDUCTION	0.0	43.5	23.2	26.5	5.6	1.1	0.1	0.1	0.0	0.0	1416	165	639.45
1960/61	REDUCTION	0.0	16.1	32.2	10.8	29.7	10.1	0.9	0.1	0.1	0.0	2799	1227	3463.55
1961/62	REDUCTION	0.0	9.7	57.4	17.9	2.6	9.9	2.4	0.1	0.0	0.0	808	146	1721.99
1962/63	REDUCTION	0.0	0.4	30.3	58.0	5.4	2.9	2.9	0.2	0.0	0.0	1087	885	4376.33
1963/64	REDUCTION	0.0	13.1	47.4	27.7	10.3	1.4	0.1	0.0	0.0	0.0	1258	198	3507.73
1964/65	REDUCTION	0.0	8.2	36.4	33.8	15.8	5.4	0.3	0.1	0.0	0.0	1750	684	1326.51
1965/66	REDUCTION	8.7	61.5	18.7	6.7	3.3	1.0	0.2	0.0	0.0	0.0	0*	25	5565.20
1966/67	REDUCTION	1.2	37.0	45.6	12.9	2.0	1.0	0.2	0.1	0.0	0.0	0*	25	2538.06
1967/68	REDUCTION	1.8	32.0	47.2	16.7	2.1	0.3	0.0	0.1	0.0	0.0	0*	25	172.48
1968/69	OTHER	16.1	27.0	23.2	22.4	9.5	1.6	0.1	0.0	0.0	0.0	0*	25	11.56
1969/70	OTHER	39.5	32.7	26.9	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0*	25	39.77
1970/71	OTHER	0.1	14.4	39.6	36.8	3.8	4.2	0.9	0.1	0.1	0.0	953	135	339.63
1971/72	ROE-SN	0.0	4.4	29.8	27.7	25.7	6.9	4.4	1.1	0.1	0.0	1837	598	762.73"
	ROE-GN	0.0	0.0	0.9	14.9	65.0	10.6	7.9	0.6	0.0	0.0	329	503	8.47
1972/73	ROE-SN	0.0	1.2	50.5	18.6	15.5	11.7	1.9	0.5	0.2	0.0	1328	593	539.55"
	ROE-GN	0.0	0.0	2.5	25.3	44.9	20.9	4.4	1.3	0.6	0.0	158	114	71.26
1973/74	ROE-SN	0.0	2.8	17.7	38.6	19.7	13.4	6.6	0.9	0.3	0.0	1587	202	282.57
	ROE-GN	0.0	0.0	0.4	22.8	37.7	24.8	12.3	1.8	0.2	0.0	496	101	332.81
1974/75	ROE-SN	0.3	1.2	32.9	25.4	27.8	8.6	3.2	0.7	0.1	0.0	8923	3300	278.78
	ROE-GN	0.0	0.0	3.3	25.6	46.2	16.4	6.4	2.1	0.0	0.0	519	117	368.42
1975/76	ROE-SN	0.0	3.0	11.8	41.2	20.9	16.8	4.5	1.5	0.2	0.0	5418	973	493.71
	ROE-GN	0.0	0.0	0.8	18.8	29.8	35.3	11.8	3.0	0.4	0.1	1222	253	383.45
1976/77	OTHER	0.0	1.0	32.8	18.7	29.8	8.1	6.6	3.0	0.0	0.0	198	144	32.75
	ROE-SN	0.0	0.7	17.4	22.6	31.8	16.6	8.5	1.9	0.4	0.0	2496	925	284.27
	ROE-GN	0.0	0.0	1.1	13.0	35.5	31.6	13.5	4.0	1.3	0.0	453	169	411.71
1977/78	ROE-SN	0.0	0.2	25.7	15.2	19.9	23.1	10.9	3.5	1.1	0.4	1396	589	354.31
	ROE-GN	0.0	0.0	1.3	8.9	29.6	38.1	17.7	3.8	0.5	0.1	1075	474	576.00
1979/80	ROE-SN	0.0	3.7	73.1	6.4	9.0	4.0	2.6	0.7	0.4	0.1	2582	1401	1.12"
	ROE-GN	0.0	0.0	3.3	2.6	24.8	23.7	26.3	11.3	6.6	1.5	274	210	32.46
1980/81	ROE-SN	0.0	2.0	12.3	66.6	8.4	7.0	2.6	0.6	0.3	0.1	2952	492	25.75"
	ROE-GN	0.0	0.3	1.5	50.7	13.6	15.4	10.6	5.5	1.8	0.7	1536	276	163.04
1981/82	ROE-SN	0.0	1.7	15.6	10.7	60.2	5.2	4.6	1.5	0.5	0.1	3508	2296	188.15"
	ROE-GN	0.0	0.0	2.4	5.9	76.0	6.7	5.9	2.3	0.7	0.1	1337	301	287.08
1982/83	ROE-SN	0.0	0.5	7.0	15.4	10.8	57.1	5.0	3.1	0.7	0.3	5445	1082	154.75
	ROE-GN	0.0	0.0	0.5	7.2	13.1	69.4	5.0	3.9	0.6	0.3	1793	994	244.49
1983/84	ROE-SN	0.0	4.4	7.3	10.1	18.2	16.1	40.7	2.3	0.8	0.1	6294	2209	284.16"
	ROE-GN	0.0	0.0	0.3	2.9	13.1	17.3	60.1	4.7	1.1	0.5	1159	338	242.25
1984/85	ROE-SN	0.0	2.7	37.5	7.5	8.6	13.1	11.9	18.2	0.4	0.1	5157	5529	222.13
	ROE-GN	0.0	0.0	3.2	5.4	9.4	19.5	22.5	38.2	1.0	0.8	1288	1407	143.53
1985/86	ROE-SN	0.0	3.9	16.4	40.2	8.6	6.3	6.7	6.1	11.3	0.5	5819	2074	163.81"
	ROE-GN	0.0	0.0	1.8	23.9	12.0	10.0	16.0	13.2	22.3	0.8	1069	262	73.95
1986/87	ROE-SN	0.0	4.1	22.6	14.6	32.2	5.7	4.5	5.8	4.7	5.8	5038	2319	193.73
	ROE-GN	0.0	0.0	0.8	7.7	44.9	11.7	7.8	9.9	8.2	9.0	981	1199	55.71
1987/88	ROE-SN	0.0	1.1	67.9	11.7	6.3	7.1	1.7	1.5	1.5	1.2	5205	2732	343.86"
	ROE-GN	0.0	0.0	4.2	10.2	14.8	27.2	15.2	7.4	10.1	10.8	566	158	59.81
1988/89	ROE-SN	0.0	1.3	4.6	76.2	9.2	3.6	2.8	0.8	0.8	0.8	5643	1937	596.32
	ROE-GN	0.0	0.0	0.3	27.6	25.1	17.3	16.5	5.8	3.7	3.8	710	259	195.14
1989/90	ROE-SN	0.0	1.0	5.6	5.1	72.7	7.5	3.8	2.9	0.7	0.8	6850	6036	400.82
	ROE-GN	0.0	0.0	0.0	1.2	65.1	16.9	6.3	7.8	1.1	1.8	847	502	190.50

FISHERY	1	2	3	4	5	6	7	8	9	10
REDUCTION	16.1	43.8	79.8	104.7	125.6	138.1	150.4	156.2	153.5	179.0
ROE-SN	16.2	54.8	88.3	114.2	135.9	154.6	170.2	183.3	195.4	205.8
ROE-GN	0.0	39.3	114.1	137.9	149.8	160.9	170.6	180.4	186.1	184.3
OTHER	16.1	49.2	84.7	110.0	131.5	147.1	161.6	172.5	186.3	201.3

Appendix table 1.4. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the northern Strait of Georgia stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	1	2	3	4	PERCENT AT AGE					8	9	10	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10 ¹¹)
						5	6	7								
1950/51	REDUCTION	0.1	3.5	45.5	38.5	9.5	2.1	0.6	0.2	0.0	0.0	0.0	0.0	3554	526	1733.55
1951/52	REDUCTION	0.1	13.0	52.2	26.4	6.8	1.5	0.1	0.0	0.0	0.0	0.0	0.0	4533	570	1857.54
1952/53	REDUCTION	0.4	12.9	49.7	30.3	4.8	1.6	0.3	0.1	0.0	0.0	0.0	0.0	5343	707	545.54
1953/54	REDUCTION	0.0	2.3	34.0	39.2	16.7	5.7	1.7	0.4	0.0	0.0	0.0	0.0	6856	2388	1934.55
1954/55	REDUCTION	0.0	5.5	40.9	44.2	7.7	1.6	0.1	0.0	0.0	0.0	0.0	0.0	2657	360	2903.78
1955/56	REDUCTION	0.0	9.5	16.4	28.1	36.9	7.4	1.2	0.4	0.1	0.0	0.0	0.0	4919	925	2587.73
1956/57	REDUCTION	0.0	0.9	36.8	25.1	24.3	11.5	1.3	0.1	0.0	0.0	0.0	0.0	2420	497	1848.17
1957/58	REDUCTION	0.0	6.4	44.3	23.4	9.5	9.6	5.8	0.8	0.1	0.0	0.0	0.0	3473	617	890.18
1958/59	REDUCTION	0.8	16.8	62.4	16.3	2.8	0.5	0.3	0.1	0.0	0.0	0.0	0.0	4454	1799	4185.81
1959/60	REDUCTION	0.0	14.1	39.7	39.2	5.8	0.8	0.3	0.1	0.0	0.0	0.1	0.1	1252	231	2428.73
1960/61	REDUCTION	0.0	21.7	22.8	30.0	22.0	3.1	0.4	0.0	0.0	0.0	0.0	0.0	1302	222	1771.58
1961/62	REDUCTION	0.0	13.3	63.4	12.7	7.2	2.8	0.6	0.0	0.0	0.0	0.0	0.0	1506	584	3439.44
1962/63	REDUCTION	0.0	20.8	48.3	24.5	3.4	1.8	0.9	0.2	0.0	0.0	0.0	0.0	1161	144	4278.29
1963/64	REDUCTION	0.0	5.8	64.7	26.5	2.3	0.6	0.1	0.0	0.0	0.0	0.0	0.0	2224	639	3714.95
1964/65	REDUCTION	0.2	14.1	53.3	28.3	2.7	1.1	0.3	0.1	0.0	0.0	0.0	0.0	2095	529	2668.48
1965/66	REDUCTION	0.0	19.5	36.8	23.0	15.9	3.2	1.6	0.0	0.0	0.0	0.0	0.0	435	77	1851.57
1966/67	REDUCTION	8.1	28.4	47.7	10.5	3.0	1.9	0.3	0.0	0.0	0.0	0.0	0.0	0*	25	1198.37
1967/68	REDUCTION	13.0	20.0	50.6	13.0	2.5	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0*	25	103.87
1968/69	OTHER	18.2	59.4	19.6	2.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0*	25	52.86
1969/70	OTHER	0.6	23.6	62.9	11.1	1.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0*	25	51.64
1970/71	OTHER	0.5	12.9	42.3	34.4	6.6	2.8	0.5	0.0	0.0	0.0	0.0	0.0	1060	239	82.74
1971/72	OTHER	0.0	1.5	27.6	36.8	26.1	5.4	2.3	0.3	0.0	0.0	0.0	0.0	1039	3596	73.26
	ROE-SN	0.0	4.0	42.3	30.3	18.4	4.0	1.0	0.0	0.0	0.0	0.0	0.0	2773	265	518.15
	ROE-GN	0.0	1.1	12.5	50.2	28.0	6.5	1.1	0.4	0.4	0.0	0.0	0.0	279	214	0.22
1972/73	OTHER	0.1	0.5	23.5	33.0	26.8	13.9	1.9	0.3	0.0	0.0	0.0	0.0	3915	1785	266.29
	ROE-SN	0.0	4.2	54.9	21.4	12.9	6.1	0.5	0.0	0.0	0.0	0.0	0.0	379	615	141.70
	ROE-GN	0.0	0.0	5.5	27.3	52.7	10.9	3.6	0.0	0.0	0.0	0.0	0.0	55	55	88.52
1973/74	ROE-GN	0.0	0.0	3.6	43.1	33.1	16.9	2.9	0.3	0.0	0.0	0.0	0.0	661	320	204.10 ¹¹
1974/75	OTHER	1.1	22.1	60.4	12.3	2.1	1.4	0.5	0.0	0.2	0.0	0.0	0.0	439	15	65.94
	ROE-SN	1.7	3.5	57.3	27.0	7.1	2.6	0.5	0.2	0.1	0.0	0.0	0.0	3092	662	50.23
	ROE-GN	0.0	0.0	6.7	31.9	43.7	13.4	3.4	0.8	0.0	0.0	0.0	0.0	119	26	283.37
1975/76	OTHER	0.1	7.9	17.6	34.9	25.5	8.6	3.7	1.3	0.2	0.1	0.0	0.0	1380	553	150.55
	ROE-SN	0.0	13.3	26.3	43.3	14.1	2.2	0.3	0.4	0.0	0.0	0.0	0.0	729	97	20.92
	ROE-GN	0.0	0.0	0.5	39.1	44.0	12.9	3.0	0.4	0.1	0.0	0.0	0.0	737	269	405.21
1976/77	OTHER	0.0	3.2	19.7	24.8	36.9	14.6	0.6	0.0	0.0	0.0	0.0	0.0	157	254	46.34
	ROE-SN	0.1	3.3	57.8	20.8	14.4	3.0	0.4	0.2	0.0	0.0	0.0	0.0	2234	1269	370.86
	ROE-GN	0.0	0.0	3.2	26.1	48.7	17.2	4.1	0.6	0.1	0.0	0.0	0.0	1423	162	466.14
1977/78	OTHER	0.1	4.7	38.0	28.4	9.6	11.6	5.7	1.2	0.5	0.1	0.0	0.0	758	205	364.13
	ROE-SN	0.0	0.8	34.8	42.8	11.9	7.7	1.5	0.3	0.0	0.1	0.0	0.0	3146	2299	353.53
	ROE-GN	0.0	0.0	0.4	19.7	31.4	35.1	11.3	1.7	0.4	0.0	0.0	0.0	462	690	426.90
1978/79	OTHER	0.0	1.2	16.2	36.6	25.3	10.9	7.7	1.6	0.4	0.1	0.0	0.0	764	201	164.24
	ROE-SN	0.0	1.0	17.7	31.0	32.5	10.2	5.8	1.5	0.2	0.0	0.0	0.0	889	311	1.00 ⁻
	ROE-GN	0.0	0.0	1.2	23.2	54.7	13.5	5.8	1.5	0.0	0.2	0.0	0.0	607	290	441.80
1979/80	OTHER	1.4	5.0	40.4	21.9	18.6	8.1	2.8	1.5	0.3	0.0	0.0	0.0	2101	1071	126.33
	ROE-SN	0.0	2.4	48.5	16.5	18.0	10.4	2.6	1.3	0.3	0.1	0.0	0.0	3548	1368	16.93
	ROE-GN	0.0	0.0	2.0	9.2	44.6	33.4	8.8	1.9	0.3	0.0	0.0	0.0	754	1139	215.21
1980/81	OTHER	0.0	1.8	40.6	36.5	13.3	4.7	2.1	0.5	0.5	0.0	0.0	0.0	655	212	26.24
	ROE-SN	0.0	6.8	36.9	30.5	11.4	9.7	3.8	0.6	0.3	0.0	0.0	0.0	7083	2254	202.01
	ROE-GN	0.0	0.1	2.2	18.2	23.0	37.4	16.1	2.8	0.3	0.1	0.0	0.0	1140	338	333.10
1981/82	OTHER	0.0	0.0	25.8	35.2	28.3	4.4	2.5	2.5	0.0	1.3	0.0	0.0	159	123	12.34
	ROE-SN	0.0	4.8	31.5	26.3	23.1	5.2	5.7	2.7	0.6	0.1	0.0	0.0	3304	1659	1.28
	ROE-GN	0.0	0.0	4.4	15.4	28.5	14.8	20.8	14.2	1.7	0.4	0.0	0.0	833	543	367.36
1982/83	OTHER	0.0	27.2	47.2	13.9	7.8	2.8	0.0	1.1	0.0	0.0	0.0	0.0	180	523	10.56
	ROE-SN	0.0	2.4	31.8	28.4	17.8	12.1	3.3	2.9	1.2	0.2	0.0	0.0	9836	6124	676.25
	ROE-GN	0.0	0.0	0.5	27.8	29.5	23.6	9.3	7.4	1.7	0.2	0.0	0.0	407	305	563.81
1983/84	OTHER	0.0	8.7	39.4	28.5	11.0	7.3	3.7	1.4	0.0	0.0	0.0	0.0	355	66	19.33
	ROE-SN	0.0	4.7	39.3	31.4	12.8	6.6	3.5	1.0	0.5	0.1	0.0	0.0	5747	1917	351.51
	ROE-GN	0.0	0.0	7.0	30.2	31.1	19.2	9.3	1.7	0.7	0.9	0.0	0.0	766	759	421.50
1984/85	OTHER	0.0	13.1	50.8	20.3	10.2	4.0	1.3	0.3	0.0	0.0	0.0	0.0	679	380	11.60
	ROE-SN	0.0	21.9	45.6	19.1	8.5	3.1	1.3	0.5	0.1	0.0	0.0	0.0	5677	2317	288.55
	ROE-GN	0.0	0.1	3.1	26.1	32.5	23.6	9.2	3.7	0.8	0.8	0.0	0.0	1096	650	237.16
1985/86	OTHER	0.0	16.3	48.8	27.9	2.3	4.7	0.0	0.0	0.0	0.0	0.0	0.0	86	86	14.64
	ROE-SN	0.1	8.9	54.8	25.9	7.1	2.2	0.8	0.2	0.1	0.0	0.0	0.0	4454	1587	17.16
1986/87	ROE-SN	0.0	5.8	32.6	38.8	17.0	4.0	1.2	0.4	0.2	0.1	0.0	0.0	6433	2405	321.49 ¹¹
	ROE-GN	0.0	0.0	2.0	32.7	34.5	17.6	9.7	2.7	0.5	0.3	0.0	0.0	1277	652	145.34
1987/88	OTHER	0.0	0.0	45.5	22.7	22.7	8.0	1.1	0.0	0.0	0.0	0.0	0.0	88	88	4.04
	ROE-SN	0.0	3.8	57.7	15.6	16.7	4.7	1.1	0.3	0.1	0.0	0.0	0.0	4996	1541	145.97
	ROE-GN	0.0	0.0	9.1	14.9	48.1	19.5	5.5	2.3	0.4	0.2	0.0	0.0	821	383	414.24
1988/89	ROE-SN	0.0	7.1	19.3	55.4	9.1	6.9	1.8	0.3	0.0	0.0	0.0	0.0	4797	1287	117.28 ¹¹
	ROE-GN	0.0	0.0	1.6	40.2	22.0	25.9	7.8	2.2	0.4	0.0	0.0	0.0	823	1143	421.70
1989/90	ROE-SN	0.0	6.6	56.2	12.1	20.3	2.8	1.5	0.4	0.1	0.0	0.0	0.0	3950	1901	1.00 ⁻
	ROE-GN	0.0	0.0	5.7	11.4	57.1	12.6	11.1	1.7	0.2	0.1	0.0	0.0	879	461	300.65

FISHERY	AVERAGE WEIGHT AT AGE (gms)									
	1	2	3	4	5	6	7	8	9	10
REDUCTION	14.9	45.4	83.4	109.8	131.7	149.2	169.7	174.4	194.0	188.3
ROE-SN	15.7	57.0	82.5	109.8	130.6	148.6	164.9	174.4	174.0	185.7
ROE-GN	0.0	67.2	118.8	137.0	148.5	159.8	167.5	179.7	177.3	188.0
OTHER	16.0	51.9	84.2	110.5	132.6	150.4	167.9	169.8	175.5	181.0

Appendix table 1.5. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the southern Strait of Georgia stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	1	2	3	4	PERCENT AT AGE					8	9	10	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10 ³)
1950/51	REDUCTION	0.0	4.7	65.6	23.5	5.1	0.9	0.1	0.0	0.0	0.0	0.0	0.0	4262	1605	2688.26
1951/52	REDUCTION	0.1	9.3	58.5	23.7	6.7	1.2	0.4	0.1	0.0	0.0	0.0	0.0	4499	1222	2966.21
1952/53	REDUCTION	0.1	3.9	65.9	26.6	3.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	3320	1258	493.14
1953/54	REDUCTION	0.0	0.7	58.4	34.2	5.9	0.6	0.1	0.0	0.0	0.0	0.0	0.0	6306	2318	4668.76
1954/55	REDUCTION	0.0	3.3	56.4	33.8	5.7	0.6	0.1	0.0	0.0	0.0	0.0	0.0	2634	714	4115.48
1955/56	REDUCTION	0.0	4.5	53.8	29.5	10.4	1.5	0.2	0.0	0.0	0.0	0.0	0.0	4913	2414	4726.81
1956/57	REDUCTION	0.0	1.6	70.8	21.0	4.2	2.0	0.3	0.1	0.0	0.0	0.0	0.0	5059	2139	4146.45
1957/58	REDUCTION	0.0	11.3	63.5	21.0	2.9	1.0	0.3	0.1	0.0	0.0	0.0	0.0	3924	1050	1379.36
1958/59	REDUCTION	0.8	17.1	64.2	14.6	2.4	0.6	0.2	0.1	0.0	0.0	0.0	0.0	5586	2067	1946.50
1959/60	REDUCTION	0.0	4.5	57.2	35.2	2.5	0.4	0.1	0.1	0.0	0.0	0.0	0.0	2490	1351	4499.74
1960/61	REDUCTION	0.0	35.7	29.1	25.5	8.8	0.8	0.1	0.0	0.0	0.0	0.0	0.0	3049	620	3469.79
1961/62	REDUCTION	0.0	5.2	76.0	13.6	3.6	1.4	0.2	0.1	0.0	0.0	0.0	0.0	1697	412	3696.98
1962/63	REDUCTION	0.0	14.4	53.6	29.2	2.6	0.2	0.1	0.0	0.0	0.0	0.0	0.0	1148	308	3870.31
1963/64	REDUCTION	0.1	6.2	56.3	34.0	2.9	0.4	0.1	0.1	0.0	0.0	0.0	0.0	1804	625	3796.46
1964/65	REDUCTION	0.0	16.2	58.1	22.6	2.3	0.7	0.0	0.0	0.2	0.0	0.0	0.0	1259	451	1965.81
1965/66	REDUCTION	0.0	31.0	32.7	23.8	11.1	1.0	0.5	0.0	0.0	0.0	0.0	0.0	416	36	1332.91
1966/67	REDUCTION	13.6	37.4	33.8	11.2	2.7	1.0	0.2	0.0	0.1	0.0	0.0	0.0	0*	25	2516.94
1967/68	REDUCTION	69.3	15.8	9.0	4.3	1.0	0.4	0.0	0.2	0.0	0.0	0.0	0.0	0*	25	245.19
1968/69	OTHER	24.6	38.1	23.0	10.4	2.8	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0*	25	60.68
1969/70	OTHER	0.4	27.4	57.2	7.8	5.1	1.0	1.1	0.0	0.0	0.0	0.0	0.0	0*	25	38.15
1970/71	OTHER	0.0	10.6	33.4	42.1	8.6	2.8	2.2	0.3	0.0	0.0	0.0	0.0	359	162	64.38
1971/72	OTHER	0.0	13.8	33.5	33.8	15.1	2.7	1.0	0.1	0.0	0.0	0.0	0.0	2625	807	154.95
	ROE-SN	0.0	14.0	28.6	36.0	17.4	2.8	1.0	0.2	0.0	0.0	0.0	0.0	2263	597	38.49
	ROE-GN	0.0	5.7	11.1	45.1	29.4	7.0	1.6	0.1	0.0	0.0	0.0	0.0	756	151	9.59
1972/73	OTHER	0.0	3.4	49.6	21.2	18.6	5.5	1.1	0.5	0.1	0.0	0.0	0.0	797	203	27.12
	ROE-GN	0.0	0.0	21.3	31.4	32.5	11.2	3.0	0.6	0.0	0.0	0.0	0.0	169	56	43.63
1973/74	OTHER	0.0	17.4	73.3	8.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	86	86	39.04
	ROE-GN	0.0	0.0	7.3	40.4	27.7	16.1	6.4	2.1	0.0	0.0	0.0	0.0	329	268	30.21
1974/75	ROE-SN	0.0	3.9	50.1	28.6	8.7	4.3	3.1	0.9	0.3	0.0	0.0	0.0	2154	597	2.49 ^h
	ROE-GN	0.0	0.0	1.6	64.5	21.0	9.7	3.2	0.0	0.0	0.0	0.0	0.0	62	62	68.22
1975/76	OTHER	0.0	5.5	21.7	44.3	19.7	5.2	2.3	0.8	0.5	0.0	0.0	0.0	3023	965	249.87
	ROE-SN	0.0	9.6	22.1	35.5	16.0	5.6	6.1	3.6	1.3	0.3	0.0	0.0	394	108	1.00-
	ROE-GN	0.0	0.0	0.7	41.5	41.5	11.6	2.7	2.0	0.0	0.0	0.0	0.0	147	126	63.84
1976/77	OTHER	0.6	4.2	52.5	21.7	15.2	3.8	1.3	0.5	0.2	0.1	0.0	0.0	2512	788	472.92
	ROE-SN	0.0	4.8	18.4	8.0	15.2	19.2	16.0	11.2	4.8	2.4	0.0	0.0	125	136	23.00
	ROE-GN	0.0	0.0	4.6	48.6	35.4	10.3	1.1	0.0	0.0	0.0	0.0	0.0	175	5	48.06
1977/78	OTHER	0.0	1.2	35.1	45.8	10.6	5.6	1.3	0.1	0.2	0.1	0.0	0.0	1709	391	819.26
	ROE-SN	0.0	1.1	40.5	46.2	7.5	4.3	0.4	0.0	0.0	0.0	0.0	0.0	279	132	1.00-
	ROE-GN	0.0	0.0	1.9	23.1	24.0	38.5	12.5	0.0	0.0	0.0	0.0	0.0	104	433	57.85
1978/79	OTHER	0.0	1.9	18.6	37.8	29.0	8.0	3.3	1.0	0.3	0.1	0.0	0.0	4699	1796	922.01
	ROE-SN	0.0	2.7	24.0	35.6	20.2	7.9	4.0	3.1	1.3	1.2	0.0	0.0	520	98	1.00-
1979/80	OTHER	0.0	1.4	45.4	24.0	17.7	8.4	1.7	1.1	0.3	0.1	0.0	0.0	2842	1954	109.21
	ROE-SN	0.0	3.0	57.9	12.0	15.9	6.8	2.9	0.8	0.2	0.5	0.0	0.0	591	189	1.00-
1980/81	OTHER	0.0	3.9	33.3	33.9	15.9	9.1	3.2	0.5	0.1	0.0	0.0	0.0	4505	2225	390.60
	ROE-SN	0.0	8.6	38.4	29.9	10.6	8.8	2.8	0.6	0.2	0.0	0.0	0.0	648	255	1.00-
1981/82	OTHER	0.0	3.6	39.0	31.5	15.3	5.8	3.9	0.8	0.1	0.0	0.0	0.0	2369	1384	303.92
	ROE-SN	0.0	8.7	39.7	23.1	17.4	3.8	4.5	2.2	0.5	0.0	0.0	0.0	2096	1168	302.55
1982/83	OTHER	0.0	0.8	16.6	32.0	23.2	13.2	4.9	5.7	3.0	0.6	0.0	0.0	1910	1526	47.33
	ROE-SN	0.0	5.8	29.8	28.7	18.3	8.7	2.8	3.8	1.6	0.5	0.0	0.0	2126	975	22.47
1983/84	OTHER	0.0	16.2	30.0	21.9	18.5	8.3	3.3	0.9	0.5	0.4	0.0	0.0	1527	555	52.95
	ROE-SN	0.0	21.9	31.4	18.8	13.4	9.3	2.6	1.5	0.6	0.3	0.0	0.0	1406	790	43.55
1984/85	OTHER	0.0	33.4	37.1	18.7	6.7	2.8	0.9	0.4	0.1	0.0	0.0	0.0	1843	288	64.51
	ROE-SN	0.0	29.3	39.1	18.5	6.3	4.2	1.5	0.9	0.1	0.0	0.0	0.0	2155	693	12.24
1985/86	OTHER	0.0	13.1	59.1	19.7	6.2	1.4	0.4	0.1	0.0	0.0	0.0	0.0	777	156	27.93
	ROE-SN	0.0	20.8	59.2	13.8	4.1	1.3	0.7	0.1	0.1	0.0	0.0	0.0	1961	542	1.00-
1986/87	OTHER	0.0	21.8	34.7	31.0	10.0	1.9	0.5	0.2	0.0	0.0	0.0	0.0	882	204	14.91
	ROE-SN	0.0	27.6	35.8	28.0	6.4	1.4	0.6	0.2	0.0	0.1	0.0	0.0	1257	246	1.00-
	ROE-GN	0.0	0.0	3.6	41.4	31.4	14.3	6.1	2.5	0.6	0.2	0.0	0.0	643	926	266.33
1987/88	OTHER	0.2	3.9	61.6	16.6	14.5	2.2	0.6	0.2	0.1	0.0	0.0	0.0	829	1087	65.03
	ROE-SN	0.0	8.0	72.3	11.1	7.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0	922	494	1.00-
1988/89	OTHER	0.0	26.5	16.6	42.9	7.1	5.9	0.9	0.2	0.0	0.0	0.0	0.0	1049	298	59.24
	ROE-SN	0.0	18.4	14.1	47.8	10.5	7.8	1.0	0.3	0.0	0.1	0.0	0.0	1633	479	59.99
1989/90	ROE-SN	0.0	11.1	59.4	7.5	15.9	3.4	2.2	0.4	0.1	0.1	0.0	0.0	1697	1549	1.00-
	ROE-GN	0.0	0.0	13.2	12.2	54.7	11.4	7.1	1.0	0.4	0.0	0.0	0.0	492	325	227.35

FISHERY	1	2	3	AVERAGE WEIGHT AT AGE (gms)							8	9	10
REDUCTION	13.1	58.5	93.8	118.6	143.0	160.3	173.8	187.2	193.1	222.2			
ROE-SN	0.0	59.9	87.6	113.1	135.6	159.9	171.4	190.5	197.9	210.4			
ROE-GN	0.0	59.4	112.8	139.3	153.1	167.2	175.8	175.3	180.8	213.0			
OTHER	15.2	56.3	89.0	112.5	135.0	158.4	168.5	181.1	194.5	209.3			

Appendix table 1.6. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the southern west coast Vancouver Island stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	1	2	3	4	PERCENT AT AGE					10	NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10 ³)
						5	6	7	8	9				
1950/51	REDUCTION	0.1	13.1	38.1	40.6	6.4	1.3	0.3	0.0	0.0	0.0	3843	551	1630.59
1951/52	REDUCTION	0.1	5.3	65.5	20.1	7.9	0.8	0.2	0.0	0.0	0.0	1686	593	1105.57
1952/53	REDUCTION	0.1	8.9	55.7	32.8	2.0	0.5	0.0	0.0	0.0	0.0	2777	1417	2.36
1953/54	REDUCTION	0.0	2.8	64.3	26.5	5.5	0.6	0.1	0.1	0.0	0.0	5730	2473	3086.25
1954/55	REDUCTION	0.0	16.8	59.4	19.7	3.4	0.6	0.0	0.0	0.0	0.0	2510	699	706.20
1955/56	REDUCTION	0.0	12.4	64.3	16.0	6.1	1.1	0.2	0.0	0.0	0.0	4653	2257	1931.15
1956/57	REDUCTION	0.0	2.7	71.9	24.8	0.3	0.2	0.0	0.0	0.0	0.0	588	497	312.93
1957/58	REDUCTION	0.0	15.6	55.3	25.0	4.0	0.1	0.0	0.0	0.0	0.0	707	432	68.62
1958/59	REDUCTION	0.0	6.4	61.0	25.1	6.0	1.0	0.1	0.2	0.1	0.0	2066	1383	4315.70
1959/60	REDUCTION	0.0	26.9	48.2	19.7	4.1	0.6	0.4	0.2	0.0	0.0	539	189	1988.85
1960/61	REDUCTION	0.0	52.7	33.9	10.0	3.1	0.2	0.0	0.0	0.0	0.0	419	54	1719.68
1961/62	REDUCTION	0.0	5.1	78.2	12.1	3.7	0.9	0.0	0.0	0.0	0.0	751	386	1659.51
1962/63	REDUCTION	0.0	3.5	44.4	45.5	5.6	0.8	0.2	0.0	0.0	0.0	886	316	404.28
1963/64	REDUCTION	0.0	2.6	60.8	25.5	10.1	0.8	0.3	0.0	0.0	0.0	1134	1003	1989.83
1964/65	REDUCTION	0.0	2.3	34.7	49.3	9.8	3.5	0.4	0.0	0.0	0.0	775	344	1141.93
1965/66	REDUCTION	0.0	0.3	41.3	33.3	21.3	2.7	1.0	0.0	0.0	0.0	300	403	636.21
1966/67	REDUCTION	2.4	20.7	55.5	16.7	3.4	0.8	0.3	0.2	0.0	0.0	0*	25	859.8
1971/72	ROE-SN	0.0	4.1	19.9	50.8	20.0	3.3	1.1	0.8	0.0	0.0	1222	843	319.50
1972/73	ROE-SN	0.0	0.9	32.3	24.1	31.0	10.1	1.3	0.3	0.1	0.0	1967	1330	678.19
	ROE-GN	0.0	0.0	7.9	22.9	51.8	13.5	2.9	1.0	0.2	0.0	624	526	63.80
1973/74	ROE-SN	0.0	12.1	45.1	25.7	11.0	5.0	1.0	0.1	0.0	0.0	3022	1434	341.88
	ROE-GN	0.0	0.0	26.1	30.7	26.1	13.6	3.4	0.0	0.0	0.0	176	30	207.72
1974/75	ROE-SN	0.0	0.7	46.5	21.9	14.2	9.4	5.7	1.4	0.2	0.0	6191	3025	901.22 ^u
	ROE-GN	0.0	0.0	3.0	30.5	37.9	21.2	7.1	0.4	0.0	0.0	269	145	407.98
1975/76	ROE-SN	0.0	0.1	7.6	45.5	20.8	14.4	8.3	2.8	0.5	0.0	7026	1218	1358.83
	ROE-GN	0.0	0.0	0.7	41.8	33.6	15.3	5.9	2.3	0.3	0.1	1238	125	932.28
1976/77	ROE-SN	0.0	0.5	11.8	32.1	37.5	12.5	4.1	1.5	0.2	0.0	6171	1298	1226.50 ^u
	ROE-GN	0.0	1.0	6.1	23.0	45.4	16.8	6.1	1.5	0.0	0.0	196	26	669.58
1977/78	OTHER	0.0	1.3	41.9	26.2	13.7	13.5	2.0	0.9	0.3	0.3	1727	416	183.29
	ROE-SN	0.0	0.5	35.1	18.7	18.6	20.8	4.8	1.3	0.2	0.1	5067	2353	381.15
	ROE-GN	0.0	0.0	1.2	5.3	20.1	49.6	17.3	5.8	0.5	0.2	417	84	730.95
1978/79	ROE-SN	0.0	0.5	9.9	39.2	18.5	16.4	11.9	2.6	0.8	0.2	2165	1149	411.88 ^u
	ROE-GN	0.0	0.0	1.0	25.1	27.2	26.3	18.0	2.1	0.4	0.0	518	214	263.70
1979/80	ROE-SN	0.0	3.5	45.0	11.4	18.2	9.2	8.4	3.5	0.7	0.1	2037	1241	146.54 ^u
	ROE-GN	0.0	0.0	0.0	4.4	40.7	25.6	16.8	11.4	0.8	0.3	386	717	36.65
1980/81	ROE-SN	0.0	4.0	37.7	26.4	10.6	11.5	6.4	2.8	0.6	0.0	3162	1247	251.13 ^u
	ROE-GN	0.0	0.0	1.8	21.0	14.9	36.3	18.9	7.1	0.0	0.0	281	81	136.27
1981/82	ROE-SN	0.0	4.0	24.8	28.7	23.5	5.3	8.5	3.1	1.7	0.4	3930	2036	201.06 ^u
	ROE-GN	0.0	0.0	0.3	17.3	39.5	11.4	23.3	5.4	2.6	0.3	352	216	49.47
1982/83	ROE-SN	0.0	4.5	23.3	22.8	21.7	16.2	4.0	5.3	1.2	1.1	2761	1911	476.41
1983/84	ROE-SN	0.0	20.5	36.8	14.1	9.6	10.5	6.1	1.1	1.1	0.2	2903	1266	485.38
1984/85	ROE-SN	0.0	21.1	50.2	16.1	4.1	2.9	3.4	1.8	0.1	0.3	2341	603	15.98 ^u
1985/86	ROE-SN	0.0	4.2	48.8	27.2	10.3	3.9	2.7	2.1	0.7	0.1	3127	1073	16.49 ^u
1986/87	ROE-SN	0.0	15.1	16.0	35.7	19.0	8.1	2.9	1.6	1.2	0.4	4050	2121	1014.35
1987/88	ROE-SN	0.0	2.5	60.9	7.3	15.5	9.2	3.1	0.8	0.5	0.3	6293	4239	666.23
	ROE-GN	0.0	0.0	5.4	7.0	40.8	29.4	12.8	3.0	1.2	0.4	500	607	86.65
1988/89	ROE-SN	0.0	2.8	15.7	62.6	6.4	8.2	3.4	0.7	0.1	0.0	4969	3549	774.27
	ROE-GN	0.0	0.0	0.3	54.5	11.0	22.3	9.4	1.6	1.0	0.0	382	145	232.76
1989/90	ROE-SN	0.0	0.5	27.1	12.4	48.0	4.5	5.7	1.5	0.2	0.1	6294	5736	534.64
	ROE-GN	0.0	0.0	1.3	7.9	69.0	8.3	10.3	2.5	0.7	0.0	445	428	127.98

FISHERY	AVERAGE WEIGHT AT AGE (gms)									
	1	2	3	4	5	6	7	8	9	10
REDUCTION	22.9	57.2	89.9	112.9	132.2	149.3	156.4	166.8	173.2	237.6
ROE-SN	21.0	63.7	94.5	124.6	149.7	170.2	184.2	194.5	204.1	206.3
ROE-GN	0.0	45.5	108.8	137.0	154.0	167.2	179.4	183.4	184.1	194.6
OTHER	22.6	60.5	92.5	119.6	141.7	160.4	171.7	188.6	197.5	206.3

Appendix table 1.7. Age composition and catch in numbers by fishery and season and weight at age averaged over all seasons for the northern west coast Vancouver Island stock assessment region. These data are used for age-structured model analysis.

SEASON	FISHERY	PERCENT AT AGE										NUMBER AGED	SAMPLE WEIGHT	CATCH (x 10 ⁶)
		1	2	3	4	5	6	7	8	9	10			
1950/51	REDUCTION	0.0	1.5	27.0	54.1	12.8	3.6	1.0	0.0	0.0	0.0	196	190	546.82
1951/52	REDUCTION	0.0	0.2	10.2	27.5	52.2	7.1	2.1	0.5	0.1	0.0	3236	3206	1263.43
1953/54	REDUCTION	0.0	0.0	46.2	44.2	6.6	2.7	0.3	0.0	0.0	0.0	364	21	494.70
1957/58	REDUCTION	0.0	9.1	38.9	30.0	9.7	6.8	4.1	1.0	0.2	0.0	483	80	4.98
1958/59	REDUCTION	0.0	1.4	24.4	30.3	25.3	7.6	5.3	4.3	1.2	0.3	1599	1014	3141.73
1959/60	REDUCTION	0.0	4.7	56.2	24.2	9.8	3.3	1.1	0.4	0.2	0.1	2338	2403	3724.70
1960/61	REDUCTION	0.0	21.4	42.7	30.6	5.2	0.0	0.0	0.0	0.0	0.0	248	57	1382.75
1961/62	REDUCTION	0.0	4.1	87.1	7.6	0.6	0.6	0.0	0.0	0.0	0.0	510	193	880.29
1962/63	REDUCTION	0.0	0.6	43.1	51.5	4.1	0.5	0.1	0.0	0.0	0.0	1372	609	1361.92
1963/64	REDUCTION	0.0	0.0	48.0	32.0	18.0	2.0	0.0	0.0	0.0	0.0	50	50	88.97
1964/65	REDUCTION	0.0	0.0	28.6	59.2	12.2	0.0	0.0	0.0	0.0	0.0	49	49	159.49
1965/66	REDUCTION	0.0	13.6	26.8	26.1	23.2	9.1	1.2	0.0	0.0	0.0	0*	25	195.14
1966/67	REDUCTION	0.0	4.7	63.6	23.9	6.1	1.5	0.1	0.1	0.0	0.0	0*	25	482.92
1971/72	ROE-SN	0.0	0.3	13.8	38.7	40.7	4.3	1.4	0.6	0.3	0.0	349	99	177.82
1972/73	ROE-SN	0.0	0.2	24.5	24.8	35.0	13.0	2.3	0.2	0.2	0.0	609	358	557.43
1973/74	ROE-SN	0.0	3.0	40.4	21.7	16.9	13.8	3.7	0.4	0.1	0.0	2398	2045	819.44
1974/75	ROE-SN	0.0	0.4	65.2	16.6	6.9	5.6	3.9	1.1	0.2	0.0	3925	2181	679.06
1975/76	ROE-SN	0.0	0.5	12.8	51.5	16.7	8.2	7.5	2.5	0.3	0.0	2204	492	259.12
	ROE-GN	0.0	0.0	0.0	15.8	38.2	21.1	18.4	6.6	0.0	0.0	76	76	115.02
1976/77	ROE-SN	0.0	0.9	19.5	20.3	33.9	11.3	8.9	3.7	1.6	0.0	575	1613	52.30
	ROE-GN	0.0	0.0	0.0	8.6	39.5	18.5	19.8	9.9	3.1	0.6	162	92	174.14
1977/78	OTHER	0.0	1.3	49.2	16.0	13.8	16.2	2.5	0.6	0.3	0.0	630	273	74.55
	ROE-SN	0.0	1.7	69.0	13.3	6.4	5.8	2.2	1.5	0.1	0.1	896	650	78.36
	ROE-GN	0.0	0.0	1.1	2.7	21.8	41.0	23.4	8.5	1.1	0.5	188	65	204.38
1978/79	ROE-SN	0.0	1.2	18.4	65.0	8.9	3.4	2.8	0.2	0.1	0.1	1720	674	455.13
	ROE-GN	0.0	0.0	3.8	34.0	20.8	13.2	28.3	0.0	0.0	0.0	53	191	293.99
1979/80	ROE-SN	0.0	1.6	41.5	22.5	30.1	3.2	1.0	0.1	0.0	0.0	966	84	1.00-
	ROE-GN	0.0	0.0	0.0	10.6	84.8	4.5	0.0	0.0	0.0	0.0	66	66	125.00
1980/81	ROE-SN	0.0	0.0	17.5	45.8	13.4	20.8	2.4	0.2	0.0	0.0	583	331	275.37
1981/82	ROE-SN	0.0	0.4	21.0	24.6	35.1	5.8	11.8	1.0	0.3	0.0	1116	790	1.00-
	ROE-GN	0.0	0.0	0.8	8.2	46.0	11.9	29.7	3.1	0.2	0.0	511	426	176.17
1982/83	ROE-SN	0.0	2.5	17.8	16.2	23.2	26.8	7.0	6.3	0.2	0.0	444	195	1.00-
	ROE-GN	0.0	0.0	0.4	14.2	23.8	44.8	6.5	9.8	0.4	0.2	571	159	176.62
1983/84	ROE-SN	0.0	42.0	44.9	4.5	1.1	2.3	3.4	0.6	1.1	0.0	176	369	1.00-
	ROE-GN	0.0	0.0	1.7	6.7	18.0	32.6	31.9	5.4	3.4	0.3	555	464	55.40
1984/85	ROE-SN	0.0	18.2	65.7	7.5	2.4	2.3	2.4	1.2	0.2	0.0	654	215	1.00-
1985/86	ROE-SN	0.0	2.5	55.6	37.4	2.1	0.9	0.9	0.6	0.1	0.0	1024	64	1.00-
1986/87	ROE-SN	0.0	12.9	20.4	26.1	36.8	2.6	0.5	0.3	0.5	0.0	658	268	1.00-
	ROE-GN	0.0	0.0	1.8	24.5	61.8	5.5	2.2	2.9	0.9	0.4	550	408	144.31
1987/88	ROE-SN	0.0	3.1	61.6	9.5	10.8	13.6	0.9	0.3	0.2	0.0	1169	644	0.02
1988/89	ROE-SN	0.0	0.9	16.9	49.5	8.0	11.5	11.9	0.8	0.4	0.0	746	241	1.00-
1989/90	ROE-SN	0.0	0.6	28.5	12.7	39.0	4.8	8.3	5.3	0.6	0.2	543	489	1.00-

FISHERY	AVERAGE WEIGHT AT AGE (gms)									
	1	2	3	4	5	6	7	8	9	10
REDUCTION	9.8	53.4	89.7	111.2	131.7	143.5	154.8	172.8	179.5	156.6
ROE-SN	0.0	62.6	92.1	121.3	146.3	167.3	179.4	187.3	195.6	207.0
ROE-GN	0.0	0.0	120.1	133.8	146.4	158.1	165.0	172.6	163.5	182.0
OTHER	9.8	59.3	91.5	117.3	140.3	158.1	171.3	183.0	190.9	192.6

Appendix table 2.1. Estimates of numbers at age, spawn and other parameters from age-structured model analysis for the Queen Charlotte Islands stock assessment region.

Season	Estimated numbers at age ($\times 10^4$) for period one								Spawn Index	Spawning Biomass (t)
	3	4	5	6	7	8	9	10		
1950/51	1753	1064	216	143	0	0	0	60	172	5200
1951/52	1828	1080	548	100	63	0	0	27	122	4746
1952/53	2565	983	417	153	24	15	0	6	254	16952
1953/54	12910	1636	627	266	98	15	9	4	451	12957
1954/55	1620	8171	983	367	154	57	9	8	277	42881
1955/56	2153	1030	5183	622	232	97	36	10	372	6947
1956/57	706	623	296	719	48	18	8	4	71	1547
1957/58	929	77	171	36	40	3	1	1	41	2812
1958/59	1945	331	25	34	5	6	0	0	367	6415
1959/60	641	745	158	10	13	2	2	0	202	5410
1960/61	2109	409	475	101	7	8	1	2	423	9288
1961/62	2597	1324	253	290	61	4	5	2	241	10253
1962/63	5140	1464	644	107	115	24	2	3	213	12085
1963/64	1125	2775	646	231	35	37	8	1	181	3551
1964/65	3013	412	829	100	22	3	4	1	76	1740
1965/66	236	113	108	86	4	1	0	0	145	2601
1966/67	226	84	52	42	31	1	0	0	33	2616
1967/68	303	137	51	31	25	18	1	0	42	3580
1968/69	381	191	86	32	19	15	11	1	59	4350
1969/70	1139	243	122	55	20	12	10	8	237	7944
1970/71	2615	726	155	78	35	13	8	11	479	15296
1971/72	2313	1667	463	99	50	22	8	12	467	19016
1972/73	6330	1389	950	251	52	26	12	11	561	24093
1973/74	5146	3827	756	479	122	25	13	11	714	37276
1974/75	4607	3137	2225	420	261	66	14	13	571	45572
1975/76	1247	2795	1822	1236	229	142	36	15	912	37315
1976/77	1598	772	1507	887	564	104	65	23	1056	30495
1977/78	1911	865	405	716	404	257	47	40	872	19365
1978/79	758	1059	442	175	271	153	97	33	652	11459
1979/80	16648	466	533	180	59	91	51	44	1059	40025
1980/81	1215	10430	282	299	93	30	47	49	1158	51693
1981/82	522	763	6287	160	160	50	16	51	992	52489
1982/83	535	325	471	3776	94	94	29	39	805	42882
1983/84	3615	325	194	272	2129	53	53	39	837	34456
1984/85	1617	2190	193	111	152	1187	30	51	773	28295
1985/86	378	985	1268	104	57	77	605	41	319	25106
1986/87	668	237	589	722	57	31	42	353	715	19643
1987/88	5240	412	142	344	417	33	18	229	570	24753
1988/89	1729	3340	263	90	219	266	21	157	1219	29948
1989/90	820	1081	2066	160	55	133	161	108	860	23918

Estimated availability at age (λ_i)
 0.43 0.62 0.89 1.00 1.00 1.00 1.00 1.00

Estimated relative selectivity at age for gillnet gear
 0.01 0.21 0.58 1.00 1.00 1.00 1.00 1.00

The coefficients for the Ricker stock-recruit curve are: $\alpha = 1.025$, $\beta = 0.6035E-04$

The estimated spawn index-escapement conversion factor is 0.263E-01

Appendix table 2.2. Estimates of numbers at age, spawn and other parameters from age-structured model analysis for the Prince Rupert District stock assessment region.

Season	Estimated numbers at age ($\times 10^6$) for period one								Spawn Index	Spawning Biomass (t)
	3	4	5	6	7	8	9	10		
1950/51	6344	8044	1111	407	33	177	1	5	1058	12295
1951/52	3310	3385	3067	298	70	6	30	1	641	4894
1952/53	3424	1836	1109	585	22	5	0	2	961	26799
1953/54	7900	2131	1137	678	354	14	3	2	835	8560
1954/55	2319	4467	814	306	117	61	2	1	869	12169
1955/56	6199	1414	1992	294	89	34	18	1	951	36802
1956/57	1996	3406	811	1086	153	46	18	10	1279	13223
1957/58	3641	879	1423	260	259	37	11	7	507	30127
1958/59	7585	2190	524	822	146	145	21	10	1285	35165
1959/60	2513	4381	1251	284	425	75	75	16	1087	31256
1960/61	12742	1483	2303	596	123	184	33	39	990	30263
1961/62	6395	5984	673	857	181	37	56	22	1530	32100
1962/63	3684	3497	2977	293	329	69	14	30	783	24844
1963/64	9598	1865	1543	1055	82	92	19	12	1185	38329
1964/65	1459	4356	942	689	419	33	37	13	501	10841
1965/66	536	551	1635	244	111	68	5	8	332	6965
1966/67	886	294	234	539	61	28	17	3	222	7149
1967/68	843	312	131	85	156	18	8	6	433	9604
1968/69	1425	451	181	73	45	84	9	7	74	6643
1969/70	7293	895	275	108	43	27	49	10	886	25085
1970/71	5218	4561	556	169	66	26	16	36	716	32373
1971/72	2509	3191	2779	332	99	39	15	31	1000	42553
1972/73	4787	1585	1933	1644	193	57	22	27	730	57723
1973/74	4281	3012	995	1204	1018	119	36	30	670	51659
1974/75	2084	2701	1865	596	695	595	70	39	814	46556
1975/76	1357	1317	1688	1156	367	428	366	66	1158	46881
1976/77	2277	857	803	1006	673	214	250	252	1438	35489
1977/78	1377	1378	499	437	510	346	110	258	750	24289
1978/79	1475	843	793	254	192	234	159	169	814	21177
1979/80	12631	914	501	440	130	101	123	172	1529	38158
1980/81	2433	7899	561	293	242	73	57	166	1175	40598
1981/82	2635	1532	4881	339	173	143	43	132	1305	44721
1982/83	3168	1661	961	3040	210	107	89	108	1826	51259
1983/84	9745	2020	1059	613	1938	134	68	126	2032	47922
1984/85	1983	6150	1256	635	352	1130	78	113	2056	46375
1985/86	1912	1241	3750	715	333	190	609	103	2084	48995
1986/87	7830	1179	753	2106	365	175	100	376	2555	48245
1987/88	7437	4919	728	436	1123	201	96	261	1865	45997
1988/89	5161	4633	2977	402	214	575	103	183	1513	48810
1989/90	3785	3214	2807	1651	199	110	297	148	1742	56708

Estimated availability at age (λ_i)
 0.38 0.55 0.79 1.00 1.00 1.00 1.00 1.00

Estimated relative selectivity at age for gillnet gear
 0.01 0.14 0.60 1.00 0.78 0.78 0.78 0.78

The coefficients for the Ricker stock-recruit curve are: $\alpha = 1.258$, $\beta = 0.4407E-04$

The estimated spawn index-escapement conversion factor is 0.354E-01

Appendix table 2.3. Estimates of numbers at age, spawn and other parameters from age-structured model analysis for the Central Coast stock assessment region.

Season	Estimated numbers at age ($\times 10^6$) for period one								Spawn Index	Spawning Biomass (t)
	3	4	5	6	7	8	9	10		
1950/51	3893	4764	840	337	0	0	14	72	834	14642
1951/52	1478	1646	1566	187	68	0	0	17	343	4068
1952/53	2332	510	413	186	17	6	0	2	629	9737
1953/54	13637	1470	311	249	111	10	4	1	487	8767
1954/55	1440	6827	475	67	48	22	2	1	553	28267
1955/56	1511	849	3595	232	32	23	10	1	394	8597
1956/57	3072	533	237	561	30	4	3	2	213	3763
1957/58	5582	960	142	33	64	3	0	1	367	16649
1958/59	6612	2877	473	63	14	28	1	0	364	9284
1959/60	1612	3002	935	103	12	3	5	0	681	30874
1960/61	2782	929	1784	542	59	7	2	3	314	10059
1961/62	8282	935	299	380	103	11	1	1	860	17195
1962/63	4035	4477	425	117	144	39	4	1	394	5498
1963/64	3825	1614	1139	52	11	14	4	0	430	7309
1964/65	1736	1198	462	189	7	2	2	1	171	7440
1965/66	1941	738	425	119	45	2	0	1	158	3718
1966/67	1516	286	173	41	8	3	0	0	322	6298
1967/68	630	289	92	37	8	2	1	0	376	7525
1968/69	693	345	166	51	20	4	1	0	172	6096
1969/70	3109	440	218	104	32	13	3	1	637	13848
1970/71	2581	1972	277	136	65	20	8	2	341	23085
1971/72	3308	1552	1157	158	77	37	11	6	435	19106
1972/73	5513	1893	765	510	67	33	16	7	964	35442
1973/74	3829	3249	1064	395	252	33	16	11	893	31685
1974/75	5135	2390	1850	508	164	103	14	11	795	41009
1975/76	2589	3177	1395	939	231	74	46	11	1426	33366
1976/77	1654	1592	1765	658	394	96	30	24	1223	32781
1977/78	2027	991	905	851	280	165	40	23	732	19670
1978/79	1488	1195	521	343	248	79	46	18	694	30252
1979/80	13948	949	762	332	218	158	50	41	1159	51933
1980/81	2488	8890	602	476	205	135	97	56	1320	59045
1981/82	2455	1581	5569	361	275	118	77	88	1302	62840
1982/83	1057	1534	970	3230	201	152	65	91	1605	47137
1983/84	877	662	939	564	1811	112	85	87	1075	30302
1984/85	3290	539	386	504	287	913	56	87	1155	31474
1985/86	1335	2013	319	213	265	149	476	75	1262	28414
1986/87	2234	824	1208	182	118	146	82	303	1160	27208
1987/88	12303	1381	490	684	100	65	80	212	1871	50573
1988/89	685	7612	834	283	386	56	36	164	1782	45173
1989/90	634	409	4354	434	139	188	28	98	1786	38848

Estimated availability at age (λ_i)

0.50 0.71 0.95 1.00 1.00 1.00 1.00 1.00

Estimated relative selectivity at age for gillnet gear

0.02 0.20 0.61 0.95 1.00 1.00 1.00 1.00

The coefficients for the Ricker stock-recruit curve are: $\alpha = 1.454$, $\beta = 0.5561E-04$

The estimated spawn index-escapement conversion factor is 0.358E-01

Appendix table 2.4. Estimates of numbers at age, spawn and other parameters from age-structured model analysis for the northern Strait of Georgia stock assessment region.

Season	Estimated numbers at age ($\times 10^6$) for period one								Spawn Index	Spawning Biomass (t)
	3	4	5	6	7	8	9	10		
1950/51	2879	1375	326	65	0	0	0	27	2795	9496
1951/52	3458	1221	380	86	17	0	0	7	2905	15256
1952/53	3386	1451	420	127	29	6	0	2	3259	24224
1953/54	7638	1947	812	234	71	16	3	1	1850	15076
1954/55	4362	4362	643	260	75	23	5	1	2493	34959
1955/56	1775	1898	1788	259	104	30	9	3	1235	15953
1956/57	1608	816	556	502	73	29	8	3	1381	8003
1957/58	2442	509	190	122	110	16	6	3	735	5400
1958/59	6646	1257	150	54	34	31	5	3	2059	13416
1959/60	3175	2312	294	33	12	8	7	2	2044	16285
1960/61	1973	1301	746	92	10	4	2	3	1558	10295
1961/62	4734	929	400	221	27	3	1	1	1450	12789
1962/63	4745	1384	224	91	50	6	1	1	1198	6312
1963/64	4994	1430	207	30	12	7	1	0	1354	7840
1964/65	2588	1396	224	29	4	2	1	0	1439	11094
1965/66	1234	585	324	49	6	1	0	0	267	1714
1966/67	1277	270	48	21	3	0	0	0	498	1873
1967/68	307	127	32	5	2	0	0	0	556	3131
1968/69	427	152	63	16	2	1	0	0	837	5306
1969/70	1477	264	91	38	9	1	1	0	2444	15772
1970/71	1565	918	164	57	23	6	1	0	2350	17806
1971/72	1246	971	562	101	35	14	4	1	1579	10919
1972/73	1824	624	391	221	40	14	6	2	1375	9811
1973/74	2789	1051	269	144	72	12	4	2	2840	16090
1974/75	3798	1770	595	119	51	24	4	2	3808	34331
1975/76	2573	2342	996	271	44	18	9	2	3745	26586
1976/77	4444	1609	1283	436	96	15	6	4	5625	39688
1977/78	3571	2606	851	547	152	32	5	3	4586	31367
1978/79	1697	2048	1285	342	182	49	10	3	4546	29235
1979/80	2980	1055	1138	586	129	67	18	5	4473	32582
1980/81	2246	1842	625	618	293	64	33	11	3017	33660
1981/82	2018	1342	1041	309	269	125	27	19	4949	27570
1982/83	1870	1276	791	526	135	114	53	19	2946	17363
1983/84	1360	955	524	219	101	24	20	13	2202	13200
1984/85	2040	704	406	139	37	16	4	5	1970	16556
1985/86	2993	1150	334	135	33	8	4	2	4074	27064
1986/87	1788	1893	726	211	85	21	5	3	3771	24669
1987/88	5182	1033	1032	358	95	38	9	4	3299	35089
1988/89	1761	3193	566	445	123	31	12	4	5424	30811
1989/90	6997	1094	1796	262	170	46	12	6	4584	49585

Estimated availability at age (λ_i)

0.71 0.97 1.00 1.00 1.00 1.00 1.00 1.00

Estimated relative selectivity at age for gillnet gear

0.02 0.19 0.57 0.93 1.00 1.00 1.00 1.00

The coefficients for the Ricker stock-recruit curve are: $\alpha = 1.224$, $\beta = 0.6082E-04$

The estimated spawn index-escapement conversion factor is 0.144

Appendix table 2.5. Estimates of numbers at age, spawn and other parameters from age-structured model analysis for the southern Strait of Georgia stock assessment region.

Season	Estimated numbers at age ($\times 10^3$) for period one								Spawn Index	Spawning Biomass (t)
	3	4	5	6	7	8	9	10		
1950/51	3595	1121	230	46	0	0	1	7	285	8490
1951/52	3452	972	227	44	9	0	0	2	685	4299
1952/53	4611	924	122	26	5	1	0	0	1735	15295
1953/54	7653	2685	491	64	14	3	1	0	1774	13258
1954/55	5855	2786	500	86	11	2	0	0	1380	20146
1955/56	4723	1998	711	123	21	3	1	0	890	8290
1956/57	4247	1154	282	92	16	3	0	0	409	4291
1957/58	2085	542	113	24	8	1	0	0	895	5772
1958/59	5372	652	141	28	6	2	0	0	1074	10763
1959/60	5034	2470	201	42	9	2	1	0	504	10378
1960/61	2513	1320	398	30	6	1	0	0	602	6453
1961/62	5567	829	206	57	4	1	0	0	324	5090
1962/63	4918	1521	98	22	6	0	0	0	489	5115
1963/64	3410	1605	182	10	2	1	0	0	513	3736
1964/65	2053	610	139	13	1	0	0	0	151	2329
1965/66	1304	483	60	12	1	0	0	0	193	1894
1966/67	1171	475	58	6	1	0	0	0	138	1526
1967/68	130	67	34	3	0	0	0	0	230	1516
1968/69	144	42	22	11	1	0	0	0	346	2191
1969/70	437	78	23	12	6	1	0	0	576	4470
1970/71	551	262	47	14	7	4	0	0	491	3761
1971/72	450	334	145	26	8	4	2	0	465	4815
1972/73	590	235	155	64	11	3	2	1	455	6577
1973/74	1000	362	135	78	29	5	2	1	699	11485
1974/75	1365	619	217	75	41	16	3	2	704	13226
1975/76	995	865	370	116	37	22	8	2	541	9583
1976/77	2033	591	444	174	51	17	10	5	315	11825
1977/78	1548	1114	281	197	73	22	8	7	696	10638
1978/79	728	766	437	100	65	26	8	5	1492	4971
1979/80	809	333	199	110	25	16	6	3	746	7817
1980/81	737	476	191	114	63	14	9	6	551	6290
1981/82	540	366	201	80	48	26	6	6	206	3353
1982/83	196	134	88	46	18	11	6	3	419	2352
1983/84	309	112	66	43	23	9	5	4	466	2884
1984/85	445	171	54	32	21	11	4	5	465	5168
1985/86	785	260	98	31	18	12	6	5	476	9087
1986/87	433	488	162	61	19	11	7	7	639	6291
1987/88	1300	259	195	30	5	3	2	2	425	9380
1988/89	394	795	157	118	18	3	2	3	630	10163
1989/90	2377	236	459	90	68	10	2	3	944	15768

Estimated availability at age (λ_i)
 0.73 0.98 1.00 1.00 1.00 1.00 1.00 1.00

Estimated relative selectivity at age for gillnet gear
 0.03 0.24 0.63 1.00 0.68 0.68 0.68 0.68

The coefficients for the Ricker stock-recruit curve are: $\alpha = 0.789$, $\beta = 0.4853E-04$

The estimated spawn index-escapement conversion factor is 0.880E-01

Appendix table 2.6. Estimates of numbers at age, spawn and other parameters from age-structured model analysis for the southern west coast Vancouver Island stock assessment region.

Season	Estimated numbers at age ($\times 10^6$) for period one								Spawn Index	Spawning Biomass (t)
	3	4	5	6	7	8	9	10		
1950/51	1234	992	147	30	0	0	0	7	475	3312
1951/52	1650	304	169	21	4	0	0	1	387	2153
1952/53	1841	479	49	22	3	1	0	0	660	8158
1953/54	3158	1173	305	31	14	2	0	0	453	3343
1954/55	1297	455	133	25	3	1	0	0	602	7664
1955/56	2169	505	184	52	10	1	0	0	597	4119
1956/57	1437	405	90	27	8	1	0	0	424	8326
1957/58	2695	740	210	46	14	4	1	0	857	15773
1958/59	4188	1689	461	130	28	9	2	1	387	7456
1959/60	1712	653	267	59	17	4	1	0	449	7184
1960/61	1302	374	158	58	13	4	1	0	396	7443
1961/62	2828	375	105	41	15	3	1	0	671	7891
1962/63	1752	797	103	27	10	4	1	0	371	7639
1963/64	3240	979	368	47	12	5	2	1	915	8923
1964/65	1232	1138	252	86	11	3	1	1	652	6842
1965/66	750	478	305	62	21	3	1	0	239	5243
1966/67	970	278	146	87	18	6	1	0	117	3216
1967/68	400	321	60	28	16	3	1	0	364	6269
1968/69	582	255	205	38	18	10	2	1	429	9293
1969/70	2388	371	163	130	24	11	7	2	959	21966
1970/71	5389	1523	237	104	83	15	7	5	1256	50388
1971/72	4294	3436	971	151	66	53	10	8	1107	45976
1972/73	5876	2677	2019	567	88	39	31	10	471	59562
1973/74	5892	3522	1485	1090	302	47	21	22	678	87586
1974/75	10466	3605	2117	853	603	169	26	24	1229	92704
1975/76	4518	6256	1997	1075	404	294	83	25	1426	60687
1976/77	2461	2778	2971	768	350	141	102	37	1558	44596
1977/78	2710	1428	1290	1153	260	125	50	50	1355	33988
1978/79	842	1525	720	513	378	92	44	36	1291	22042
1979/80	2035	496	763	313	200	154	38	33	1264	24858
1980/81	1664	1234	295	443	179	115	89	40	1272	24487
1981/82	1042	964	686	150	210	87	56	63	821	19802
1982/83	912	615	546	374	80	113	47	64	534	14589
1983/84	1577	473	284	247	169	36	51	50	799	17050
1984/85	2309	831	231	136	118	81	17	48	844	33522
1985/86	2916	1464	527	147	87	75	51	42	944	38046
1986/87	1086	1851	929	334	93	55	48	59	1138	27041
1987/88	5796	536	822	401	144	40	24	46	1617	32958
1988/89	846	3295	273	390	182	67	19	32	1365	27557
1989/90	1176	418	1522	108	137	67	25	19	1189	18552

Estimated availability at age (λ_i)

0.72 0.94 1.00 1.00 1.00 1.00 1.00 1.00

Estimated relative selectivity at age for gillnet gear

0.02 0.23 0.64 1.00 0.85 0.85 0.85 0.85

The coefficients for the Ricker stock-recruit curve are: $\alpha = 0.787$, $\beta = 0.3345E-04$

The estimated spawn index-escapement conversion factor is 0.471E-01

Appendix table 2.7. Estimates of numbers at age, spawn and other parameters from age-structured model analysis for the northern west coast Vancouver Island stock assessment region.

Season	Estimated numbers at age ($\times 10^6$) for period one								Spawn Index	Spawning Biomass (t)
	3	4	5	6	7	8	9	10		
1950/51	1294	2211	320	94	0	0	0	26	546	17778
1951/52	632	712	1161	163	47	0	0	13	232	6109
1952/53	2187	306	193	248	34	10	0	3	614	14636
1953/54	1229	1395	195	123	158	22	6	2	483	14504
1954/55	1157	622	731	99	62	80	11	4	350	19068
1955/56	1286	738	397	466	63	40	51	10	1063	20057
1956/57	2846	820	470	253	297	40	25	39	1617	30213
1957/58	2902	1814	523	300	161	190	26	41	545	28167
1958/59	2911	1849	1156	333	191	103	121	42	492	7188
1959/60	2917	1281	402	176	50	29	15	24	80	2433
1960/61	1204	349	173	23	9	3	2	2	185	3370
1961/62	2797	215	81	29	4	2	0	1	569	12196
1962/63	1279	1191	96	34	12	2	1	0	112	2998
1963/64	1036	380	248	14	5	2	0	0	540	9137
1964/65	519	621	226	146	8	3	1	0	536	9461
1965/66	489	291	346	123	79	4	2	1	239	8393
1966/67	753	282	152	175	62	40	2	1	329	8030
1967/68	289	294	120	59	68	24	16	1	240	7287
1968/69	299	185	187	76	38	43	15	11	261	7839
1969/70	1323	190	118	119	49	24	28	17	468	13708
1970/71	2583	844	121	75	76	31	15	28	430	25085
1971/72	1849	1647	538	77	48	49	20	28	822	20694
1972/73	1542	1155	952	306	44	27	28	27	442	20221
1973/74	1787	852	561	440	141	20	13	25	241	16824
1974/75	2587	819	372	227	178	57	8	15	434	22646
1975/76	700	1242	411	179	109	85	27	11	394	13501
1976/77	745	414	642	186	75	42	33	15	443	10537
1977/78	2879	464	236	309	79	27	15	17	479	14359
1978/79	648	1742	251	98	106	22	7	9	825	8921
1979/80	1447	321	698	58	16	11	2	2	587	10630
1980/81	607	920	191	353	26	6	4	2	508	9019
1981/82	234	339	455	91	167	12	3	3	544	6758
1982/83	131	148	197	213	36	55	4	2	403	3765
1983/84	377	82	81	75	61	7	11	1	291	6289
1984/85	1828	239	49	39	32	22	3	4	188	11124
1985/86	1084	1165	152	31	25	20	14	5	487	18127
1986/87	481	691	742	97	20	16	13	12	560	17551
1987/88	1959	305	414	384	45	8	7	10	571	24759
1988/89	532	1249	195	264	245	29	5	11	251	20939
1989/90	854	339	796	124	168	156	18	10	506	21302

Estimated availability at age (λ_i)
 0.72 0.86 1.00 1.00 1.00 1.00 1.00 1.00

Estimated relative selectivity at age for gillnet gear
 0.01 0.16 0.47 0.71 1.00 1.00 1.00 1.00

The coefficients for the Ricker stock-recruit curve are: alpha = 0.423, beta = 0.4453E-04

The estimated spawn index-escapement conversion factor is 0.354E-01